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Sources of Copper Air Emissions

Engineering-Science, Inc., Durham, NC

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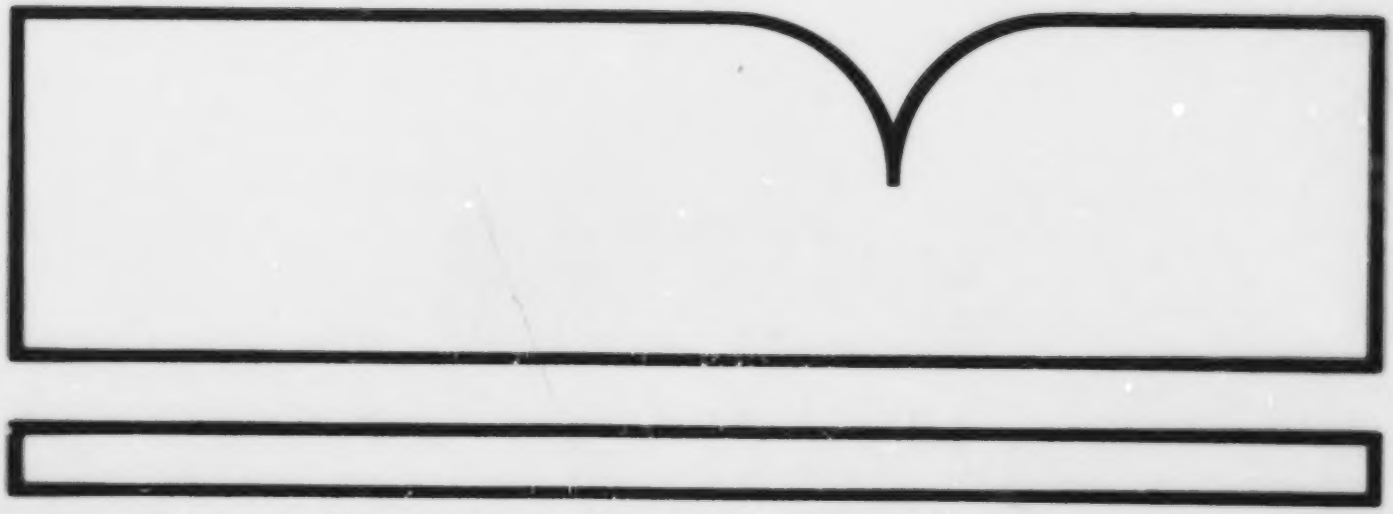

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SOURCES OF COPPER AIR EMISSIONS

by

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16. ABSTRACT The report gives results of a study to update estimates of atmospheric emissions of copper and copper compounds in the U.S. Source categories evaluated included: metallic minerals, primary copper smelters, iron and steel making, combustion, municipal incineration, secondary copper smelters, copper compound production, iron foundries, primary lead smelters, primary zinc smelters, ferroalloy production, brass/bronze production, and carbon black production. The study relied on data in published literature, supplemented by EPA test reports and data bases. The approach used to assess each source category involved: (1) estimating total particulate emissions, including fugitives; (2) determining the effect of air pollution control on emissions; (3) estimating the proportion of copper contained in the total particulates; and (4) estimating copper emissions. Copper emissions estimates are presented for each source category.

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ABSTRACT

A study was conducted to update estimates of atmospheric emissions of copper and copper compounds in the United States. Source categories evaluated included the following: metallic minerals, primary copper smelters, iron and steel, combustion, municipal incineration, secondary copper smelters, copper compound production, iron foundries, primary lead smelters, primary zinc smelters, ferroalloys, brass and bronze, and carbon black. The study relied on existing data contained in published literature, supplimented by EPA test reports and data bases. The approach used to assess each source category involved 1) estimating total particulate emissions, including fugitives; 2) determining the effect of air pollution control on emissions; 3) estimating the proportion of copper contained in the total particulates; and 4) estimating copper emissions. Copper emissions estimates are presented for each source category.

This report was submitted in fulfillment of Contract Number 68-02-3509, Work Assignment 60 by Engineering-Science under the sponsorship of the United States Environmental Protection Agency. This report covers a period from February 1984 to December 1984, and work was completed as of January 1985.

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SECTION 1

INTRODUCTION

This report provides preliminary information on sources of air emissions of copper and copper compounds. The thirteen source categories examined in this study were metallic minerals, primary copper smelters, iron and steel, combustion, municipal incinerators, secondary copper smelters, copper compounds, iron foundries, primary lead smelters, primary zinc smelters, ferroalloys, brass and bronze, and carbon black.

The collection of information for this study concentrated on existing EPA and open literature documents. These were supplemented with examinations of EPA test reports and data bases (e.g., FPEIS) for additional data.

PURPOSE

The purpose of this study was to collect information on the air emission sources of copper and copper compounds. These sources were characterized by copper emission quantities and stack parameters (e.g., height, flow, and temperature) on individual plants, where possible. Each point source within the plant was characterized.

The information collected by this study will be used in a population exposure assessment for copper. The exposure assessment will use EPA's Human Exposure Model to estimate ambient copper concentrations and to determine the level of population exposure.

STUDY METHODOLOGY

The approach used to access each source category for copper emissions involved estimating total particulate emissions, determining current control technologies and emission reduction, and estimating copper emissions. Each step is discussed below.

The estimation of total particulate emissions was a necessary first step because most of the copper data were in the form of weight percentages of particulate matter. Total particulate emissions (both process and fugitive) from each facility in a source category were estimated using emission factors derived from either EPA summary reports or EPA source test measurements. In some cases, such as iron foundries, individual plants were too numerous to allow a plant-by-plant emission estimate, and total nationwide emissions were estimated. Throughout this report, the methods used for calculating the emissions are summarized for each source category.

For most source categories, individual plant-specific control devices were used to estimate controlled particulate emissions. For some source categories, an overall control efficiency was assumed. This assumption was

made because of either a large number of sources (e.g., combustion) or a lack of individual plant process or control device data (e.g., brass and bronze).

In most cases, copper weight percentage factors were applied to controlled particulate emissions. Thus, it was assumed that copper was present in the form of particulate matter and was controlled at the same efficiency. It was also assumed that the copper concentration was not particle size dependent. In a few cases, actual copper control efficiencies were presented.

REPORT OUTLINE

Following this introduction, are the conclusions, and the three major sections of the report discuss the distribution and properties of copper, the uses of copper, and the sources of copper emissions. One appendix follows these sections. The appendix shows detailed emission calculations for one of the 15 primary copper smelters. A process flow sheet also accompanies these calculations.

SECTION 2

CONCLUSIONS

A number of sources emit or have the potential to emit copper and copper compounds. The following table provides a summary of the estimated copper emissions from the source categories investigated. These emissions are provided as ranges which represent the variability found in the available data.

Source	Estimated copper emissions (10^3 kg/yr)
Copper and iron ore processing	480 - 660
Primary copper smelting	43 - 6,000
Iron and steel making	112 - 240
Coal and oil combustion	45 - 360
Municipal incineration	3.3 - 270
Secondary copper smelting	160
Miscellaneous sources	
Copper sulfate production	45
Gray iron foundries	7.9
Primary lead smelting	5.5 - 65
Primary zinc smelting	24 - 340
Ferroalloy production	1.9 - 3.2
Brass and bronze production	1.8 - 36
Carbon black production	13

SECTION 3

DISTRIBUTION AND PROPERTIES OF COPPER

Copper, in a natural state, is widely distributed in the world, both in its native form and combined with iron, sulfur, carbon, oxygen, and other substances. Native copper deposits are numerous, but are commercially mineable only in Michigan. Native copper also occurs as a secondary mineral in some sulfide deposits in the southwestern United States.

Over one hundred and fifty copper minerals are known to exist.[1] Only a few of those minerals are commercially important. These are:

Mineral	Approximate percentage of total world copper mineral production[1]
Chalcocite (Cu_2S)	50
Chalcopyrite ($Cu\ FeS_2$)	25
Oxidized (chiefly malachite)	15
Native copper	6
Enargite ($Cu_3As_5S_4$)	3
Other sulfides	1

Copper, as related to other elements, is the 14th most abundant in the solar atmosphere, 26th in total cosmic abundance, and 23rd in average crystalline rocks.[2] Some typical concentrations of copper in various substances are shown below.[2,3]

Substance	Average concentration (ppm wt.)
Average in crystalline rocks	55
Igneous rocks	
Ultramafic	10
Basaltic	87
Diabase	110
Granite	
High calcium	30
Low calcium	10
Syenite	5
Sedimentary rocks	
Shale	45
Sandstone	1
Carbonate	4
Oceanic sediments	
Carbonate	30
Clay	2500
Sea water	3×10^{-3}

Physically, copper is a tough, soft, and ductile metal with a very high (second only to silver) thermal and electrical conductivity. Two stable nuclides are known to exist; Cu^{63}, 69.1 percent and Cu^{65}, 30.9 percent.[4] The physical properties of elemental copper are shown below.[1,5]

Property	Value
Atomic number	29
Atomic weight	63.54
Melting point	1083°C
Boiling point	2582°C
Crystal structure	Face-centered cubic a = 3.615 Å
Density @ 20°c	8.94 g/cc
Elastic modulus in tension	17,000,000 psi (annealed)
Poison's ratio	0.33
Tensile strength	32,000-37,000 psi (annealed) 55,000-61,000 psi (drawn)
Surface tension	1104 dynes/cm @1150°C
Viscosity	0.0341 cgs units @1145°C

Chemically, copper displays three oxidation states (i.e., +1, +2, and +3). Cuprous (+1) and cupric (+2) compounds are numerous, while the +3 state occurs only in a few unstable compounds. In aqueous solutions, the cupric state is more stable except in the presence of complexing groups, such as chloride or cyanide ions, ammonia, or acetonitrite. At elevated temperatures, binary cupric compounds decompose to cuprous compounds. This is especially true of CuO and CuS.

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SECTION 4

USES OF COPPER

Copper metal and copper products are used in a variety of applications in the United States. The flow chart (Figure 1) shows the copper supply/ demand relationships for 1981. Figure 1 was adopted from a 1978 supply/ demand flow chart[1] by updating production and end-use figures with information from Reference 2. The figure does not separately account for the government stockpile of strategic materials. This quantity is included in the industry stocks figure.

The end-use totals account for a number of different products as outlined below.[1,2]

Electrical Equipment and Supplies

Electric motors, power generators, motor generator sets, dynamotors, fans, blowers, industrial controls, electrical instruments and test equipment, power distribution systems (transformers, bus bars, and switchgear), electrical lighting and wiring equipment, underground power transmission lines, and smaller gage wire.

Construction Materials

Roofing and plumbing materials and brass and bronze for decorative uses.

Machinery

Nonelectrical industrial air conditioning, farm machinery, and tubing and valves in saltwater desalination plants.

Transportation

Automobiles, railroads, airplanes as air conditioning parts; in mechanisms for power brakes, windows, seats, and steering; and other devices such as radiators, heaters, defrosters, bearings, bushings, carburators, oil lines, and wiring.

Other

Ordnance including shell casings, projectile fuses and rotating bands and fire control equipment; copper chemicals; inorganic pigments; coinage; mechanisms in watches, clocks, microscopes, projectors, and gages; and other such as utensils, jewelry, furnishings, and decorative items.

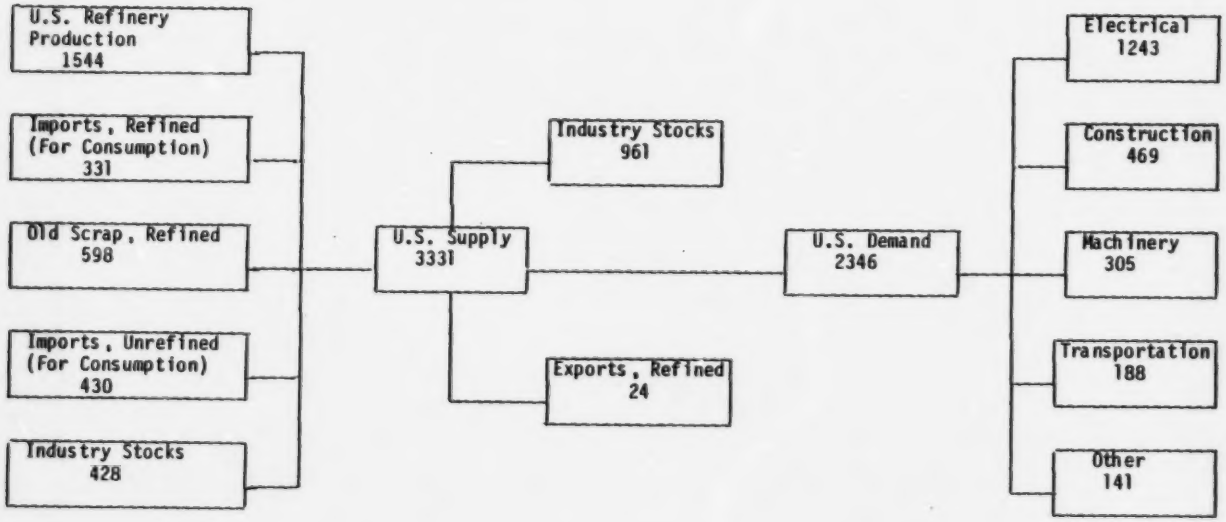

Figure 1. Estimated Copper Supply/Demand Relationship for 1981.
(Thousands of Mg Copper)

REFERENCES FOR SECTION 4

1. "Copper," in Mineral Facts and Problems, 1980 Edition, Bu. Mines Bulletin 671, 1980.

2. Butterman, W.C., "Copper," in Minerals Yearbook, 1981, Bu. Mines, 1983.

SECTION 5

SOURCES OF COPPER EMISSIONS

Copper is emitted by a variety of source categories. Many of the major sources have been investigated in detail. Table 1 lists the primary sources of copper emissions and the estimated total percent of these emissions.

TABLE 1. SOURCES OF COPPER AIR EMISSIONS[1]

Source	Proportion of total emissions (%)
Primary copper	66
Iron and steel	21
Power plant boilers	5
Incinerators	3
Secondary copper	<2
Miscellaneous copper chemicals and products	<2
Industrial boilers	1
Others*	<2

* Includes gray iron foundries, miscellaneous copper metals and alloys, and residential/commercial boilers.

Three summary studies of copper emissions have been completed since 1969.[1,2,3] The results of these studies are presented in Table 2. Although the emission estimates presented in Table 2 are dated, the relative magnitudes of the emissions serve as the basis for an updated copperemission source listing. This study is a result of this updated source listing.

In the population-exposure evaluation of copper emissions, the total nationwide emissions are not important. Sources with minor nationwide emissions may have high population exposure potential. Therefore, emissions information on all the sources listed in Table 2 and on other sources was collected, if available.

TABLE 2. SOURCES OF COPPER EMISSIONS - RESULTS OF SUMMARY STUDIES[1,2,3]

Source	Estimated copper emissions (10^3kg/yr) 1969 study[2]	1972 study[1]	1977 study[3]
Copper mining & milling	172	172	NC
Primary copper			
Roasting		2631	
Reverberatory furnace		1128	
Converters		3383	
Materials handling		751	
Total	7893	7893	NC
Secondary copper			
Scrap production		5	
Wire burning		141	
Sweating furnace		14	
Blast furnace		14	
Smelting, reverberatory		14	
Smelting, rotary		5	
Total	191	193	NC
Iron and steel			
Blast furnace		971	
Open hearth furnace		1406	
Basic oxygen furnace		64	
Electric arc furnace		64	
Total	2504	2505	NC
Gray iron foundries	45	45	NC
Miscellaneous copper metals and alloys	NC	2	NC
Miscellaneous copper chemicals and products	209	209	35*
Incinerators	417	417	NC
Combustion sources			
Utility boilers			
Coal-fired		610	1131
Oil-fired		14	653
Industrial boilers			
Coal-fired		118	113
Oil-fired		10	301
Residential/commercial boilers			
Coal-fired		7	75
Oil-fired		23	284
Total coal-fired boilers	934	735	1319
Total oil-fired boilers	45	47	1238
Total combustion	979	782	2557
Total copper emissions	12,410	12,21[illegible]	2557**

NC = Not covered by study
* Copper sulfate emissions from copper sulfate-pentahydate production
** Covers combustion sources and copper sulfate production only

The sources of copper emissions are examined in the following sections. Source categories are metallic minerals, primary copper smelters, iron and steel, combustion, municipal incinerators, secondary copper smelters, and miscellaneous sources. The sources listed in Table 2, as well as additional ones, are discussed in these sections.

METALLIC MINERAL PROCESSING

The processing of metallic mineral ores generates particulate emissions during crushing, screening, milling, and materials handling and storage. Metalic ores can contain copper, as well as other metals. In many cases, more than one metal is recovered from a particular metallic ore.

During the development of the NSPS for metallic mineral processing plants, plants, emission tests and elemental analyses of emissions were performed on some operations.[4,5] The results of these tests showed large variations in the emissions.[5] Due to this variation, an uncontrolled emission factor of 6.0 kg/Mg was used in the emission calculations.[6] This emission factor represents the emissions leaving the plant property (i.e., suspended emissions) and is probably high. An assumed control efficiency of 95 percent was applied to this emission factor, and the controlled emission factor of 0.3 kg/Mg resulted.

The literature on the composition of metallic ores is incomplete. During the tests performed on metallic mineral processing plants, elemental analyses were conducted on the particulate emissions from copper, gold, iron, uranium, vanadium, and zinc ore processing plants. The results are shown in Table 3.

TABLE 3. METALLIC MINERAL PROCESSING - COPPER COMPOSITION OF EMISSIONS*

Metallic mineral	Source	Copper content of emissions (wt.%)
Copper	Unknown	MC
	Secondary crusher	0.05
	Conveyor exhaust	MC
Gold	Primary crusher	0.001
Iron	Secondary crusher	0.18
Uranium	Dryer	0.001
Vanadium	Grinder	0.005
	Dryer	0.001
Zinc	Elevator, screen, tertiary crusher, and rod mill	0.0002

MC = Major Component
*Results taken from EMB Test Reports (79-MET-1, 79-MET-3, 79-MET-4, 80-MET-6, 80-MET-7, and 80-MET-8)

Calculations of copper emissions are based on the copper content percentages from Table 3 and the controlled emission factors, except for copper ore processing. Calculations of the copper emissions from copper ore processing plants are based on the ore grade and the controlled emission factors. The calculations showed negligible emissions from all sources except copper and iron ore processing.

The low copper values for zinc processing may be misleading. Commonly, lead/zinc processing operations also recover copper. Of the twenty-five largest zinc producing mines, at least six also recover copper.[7]

The estimated copper emissions from copper ore processing are shown in Table 4. The plant listing, ore grade, and the quantity of ore processed were taken from reference 4. If an ore grade was not specified, 0.50 percent was used. If the quantity of ore processed was not specified, an average ore processed/concentrator capacity ratio was used to estimate this quantity.

The HEM data inputs are highly variable from plant to plant. Suggested HEM inputs are shown below. These inputs are based on information in Reference 5 and estimates.

Stack Height - 10 m
Flow - 50 m^3/sec
Temperature - 298°K

The estimated copper emissions from iron ore processing are shown in Table 5. The plant listing and quantity of ore processed were taken from reference 4. If the quantity of ore processed was not specified, an average ore processed/concentrator capacity ratio of 357.8 times the concentration capacity was used to estimate this quantity. This ratio was calculated from the "ore processed" and "concentrator capacity" columns in Table 9-21 of Reference 4.

Like copper ore processing, the HEM inputs for iron ore processing are highly variable. Suggested inputs are shown here.

Stack Height - 10 m
Flow - 65 m^3/sec
Temperature - 298°K

TABLE 4. ESTIMATED COPPER EMISSIONS - COPPER ORE PROCESSING PLANTS[4]

Company	Plant	Location	Ore grade (%)	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Anaconda Co. Mineral Resources Group	Anaconda Reduction Dept.	Deer Lodge County, MT	0.50[A]	3.6[B]	5.4
Anaconda Co. Mineral Resources Group	Butte Operations	Silver Bow County, MT	0.64	17.0	33
Anaconda Co. Mineral Resources Group	Carr Fork	Tooele, UT	0.50[A]	2.8[B]	4.2
Anamax Mining Co.	Twin Buttes Operations	Sahuarita, AZ	0.50[A]	5.8	8.7
Asarco Inc.	Mission Unit	Sahuarita, AZ	0.60	7.1	13
Asarco Inc.	Silver Bell Unit	Silver Bell, AZ	0.50[A]	0.9-9.1	1.4-14
Asarco Inc.	Sacaton Unit	Casa Grande, AZ	0.68	3.8	7.8
Asarco Inc.	San Xavier Unit	Sahuarita, AZ	0.80	0.9-9.1	2.2-22
Cities Service Co.	Pinto Valley Operations	Miami, AZ	0.49	>9.1	>13
Cities Service Co.	Copperhill Operations	Copperhill, TN	0.50[A]	1.9	2.9

TABLE 4. Continued

Company	Plant	Location	Ore grade (%)	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Cyprus Mines Corp.	Cyprus Bagdad	Bagdad, AZ	0.50	12.2	18
Cyprus Pima Mining[C]	Pima Operations	Tucson, AZ	0.468	15.9[B]	22
Duval Corp.	Mineral Park Property	Kingman, AZ	0.262	5.9	4.5
Duval Corp.	Esperanza	Sahuarita, AZ	0.50[A]	0.9-9.1	1.4-14
Duval Corp.	Sierrita Property	Sahuarita, AZ	0.50[A]	30.4	45
Duval Corp.	Battle Mountain Properties	Battle Mt., NV	0.62	0.7	1.3
Earth Resources Co.	Nacimiento Copper Mine	Cuba, NM	0.70	C	--
Federal Resources Corp.	Bonney-Miser's Chest and '85	Lordsberg, NM	0.50[A]	C	--
Inspiration Consolidated Copper Company	Inspiration Division	Inspiration, AZ	0.70	0.9-9.1	1.9-19
Inspiration Consolidated Copper Company	Christmas Division	Inspiration, AZ	0.74	0.5-0.9	1.1-2.0

TABLE 4. Continued

Company	Plant	Location	Ore grade (%)	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Kennecott Copper Corp., Metal Mining Division	Ray Mines Division	Hayden, AZ	0.9	9.1	>24
Kennecott Copper Corp., Metal Mining Division	Nevada Mines Division	McGill, NV	0.74	0.5-0.9	1.1-2.0
Kennecott Copper Corp., Metal Minig Division	Chino Mines	Hurley, NM	0.87	0.9-9.1	2.3-24
Kennecott Copper Corp., Metal Minnig Division	Utah Copper Division	Salt Lake City, UT	0.61	9.1	>17
Kerramerican, Inc.	Blue Hill Joint Venture	Blue Hill, ME	1.1	0.3[B]	1.0
Keystone Wallace Resources	Minerals Division	Moab, UT	1.2	<0.1	<0.4
Magma Copper Co.	San Manuel Division	San Manuel, AZ	0.7	17.9	38
Magma Copper Co.	Superior Division	Superior, AZ	4.5	0.9	12
Micro Copper Corp.	Lisbon Valley Mine	Moab, UT	1.0	0.1[B]	0.3
Oracle Ridge Mining Partners	Oracle Ridge Project	Oracle, AZ	0.50[A]	12.8[B]	19

TABLE 4. Continued

Company	Plant	Location	Ore grade (%)	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Phelps Dodge Corp.	Copper Queen	Bisbee, AZ	0.50[A]	5.5[B]	8.3
Phelps Dodge Corp.	Morenci Branch	Morenci, AZ	0.81	>9.1	>22
Phelps Dodge Corp.	Morenci Branch/ Metcalf	Morenci, AZ	0.70	>9.1	>19
Phelps Dodge Corp.	New Cornelia Branch	Ajo, AZ	0.64	6.2-8.5	12-16
Phelps Dodge Corp.	Tyrone Branch	Tyrone, NM	0.78	>9.1	>21
Ranchers Exploration & Development Corp.	Bluebird Mine	Miami, AZ	0.40	<0.1	<0.1
San Pedro Mining corp.	San Pedro Mine	Albuquerque, N.M.	2.15	0.1	0.6
Toledo Mining Co.	OK Mine	Salt Lake City, UT	0.50[A]	Unknown	--
UV Industries, Inc.	Continental Mine & Shafts 2,3, and 4	Hanover, NM	0.50[A]	0.5	0.8
Vekol Copper	Vekol Hills Operations	Vekol Hills, AZ	0.543	5.5[B,D]	9.0

TABLE 4. Continued

Company	Plant	Location	Ore grade (%)	Ore processed (10^6 Mg/yr)	Estimted copper emissions* (10^3 kg/yr)
White Pine Copper Co.	White Pine Operations	White Pine, MI	1.3	0.9-9.1	3.5-36
TOTAL					400-520

* Estimated leaving plant property, assuming 95% control efficiency
A Assumed to be 0.50%
B Estimated by multiplying concentrator capacity by 300 (average ratio of ore processed to concentrator capacity calculated from values in Table 9-13, Reference 4)
C Inactive
D Under construction 1981

TABLE 5. Estimated Copper Emissions - Iron Ore Processing Plants[4]

Company	Plant	Location	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
CF & I Steel Corp.	Sunrise Mine	Sunrise, WY	0.5-0.9	0.3-0.5
Cleveland-Cliffs Iron Co.	Canisteo Operations	Taconite, MN	0.9-9.1	0.5-4.9
Cleveland-Cliffs Iron Co.	Ore Improvement Plant	Ishpeming, MI	1.6	0.9
Dominion Foundries and Steel Limited	Eveleth Expansion Co.	Eveleth, MN	9.5	5.1
Empire Iron Mining Co.	Palmer Operations	Ishpeming, MI	>9.1	>4.9
Eveleth Mines	Fairlane Plant	Eveleth, MN	15.6	8.4
Halecrest Co., Inc.	Mt. Hope Iron Mine	Mt. Hope, NJ	2.2[A]	1.2
Hanna Mining Co.	Groveland Mine	Iron Mtn., MI	0.9-9.1	0.5-4.9
Hanna Mining Company	National Steel Pellet Project	Keewatin, MN	0.9-9.1	0.5-4.9
Hanna Mining Company	Butler Taconite	Nashwauk, MN	0.9-9.1	0.5-4.9
Hanna Mining Company[d]	Whitney Mine	Hibbing, MN	8.7[A]	4.7

TABLE 5. Continued

Company	Plant	Location	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Hanna Mining Company	Pilot Knob	Ironton, MO	0.9-9.1	0.5-4.9
Inland Steel Mining Co.	Minerva Opertions	Virginia, MN	6.1	3.3
Jackson County Iron Co.	Black River Falls Operations	Black River Falls, WI	1.9	1.0
Jones & Laughlin Steel Corporation	Hill Annex Mine	Calumet, MN	0.9-9.1	0.5-4.9
Jones & Laughlin Steel Corporation	Lind & Greenway Mine	Grand Rapids, MN	7.2[A]	3.9
Jones & Laughlin Steel Corporation	McKinley Mine	McKinley, MN	0.9-9.1	0.5-4.9
Jones & Laughlin Steel Corporation	New York Ore Benson Mine	Star Lake, NY	0.9-9.1	0.5-4.9
Kaiser Steel Corp.	Eagle Mountain Iron Ore Mine	Eagle Mountain, CA	8.1	4.4
Long Star Steel Co.	Lone Star Mines	Lone Star, TX	0.9-9.1	0.5-4.9
Marquette Iron Mining Company	Republic Mine	Ishpeming, MN	0.9-9.1	0.5-4.9
NL Industries, Inc.	MacIntyre Development	Tahawus, NY	0.1-0.5	0.1-0.3
Picklands Mather & Co.	Erie Mining Co. Hoyt Lakes Operations	Hoyt Lakes, MN	>9.1	>4.9

TABLE 5. Continued

Company	Plant	Location	Ore processed (10^6 Mg/yr)	Estimated copper emissions* (10^3 kg/yr)
Picklands Mather & Co.	Hibbing Taconite Co.	Hibbing, MN	0.9-9.1	0.5-4.9
Pittsburgh Pacific Co.	Mesabi Division Open Pits	Hibbing, MN	0.2	0.1
Pittsburgh Pacific Co.	Neville Mine	Hibbing, MN	2.7[A]	1.5
Pittsburgh Pacific Co.	Julia Concentrator	Hibbing, MN	0.5	0.3
Pittsburgh Pacific Co.	Virginia Concentrator	Crosby, MN	2.5[A]	1.4
Pittsburgh Pacific Co.	Knox Extention	Hibbing, MN	4.0[A]	2.2
Reserve Mining Co.	Silver Bay Division	Silver Bay, MN	26.8	14.5
Rhude & Fryberger, Incorporated	Gross-Nelsonn Mine	Eveleth, MN	0.1-0.5	0.1-0.3
Rhude & Fryberge, Incorporated	Rana Mine	Kinney, MN	0.1-0.5	0.1-0.3
Standard Slag Company	Beck Iron Mine	Tecopa, CA	0.5-0.9	0.3-0.5

TABLE 5. Concluded

Company	Plant	Location	Ore processed (10^6 Mg/yr)	Estimated Copper Emissions* (10^3 kg/yr)
Tex-Iron, Incorporated	Henderson County Operations	La Rue, TX	0.1	0.1
Tilden Mining Company	Tilden Mine	Tilden Township, MI	0.9-9.1	0.5-4.9
United States Steel Corporation	Arcturus Mine	Marble, MN	0.9-9.1	0.5-4.9
United States Steel Corporation	Sherman Mine	Chisholm, MN	2.6	1.4
United States Steel Corporation	Plummer Mine	Taconite, MN	1.1	0.6
United States Steel Corporation	Minntac Mine and Plant	Mt. Iron, MN	11.4	6.2
United Stated Steel Corporation	Atlantic City Mine	Atlantic City, WY	4.5	2.4
Utah International, Incorporated	Iron Springs	Cedar City, UT	0.5-0.9	0.3-0.5
TOTAL				81->140

A = Calculated by ratio

* Estimated copper emissions calculated by using an emission factor of 0.3 kg/Mg and a copper content of 0.18 weight percent (see Table 3).

PRIMARY COPPER SMELTERS

Copper ores are currently smelted at fifteen primary copper smelters in the United States. ASARCO, Inc. has announced plans to close its primary smelter in Tacoma, Washington during June 1985.[8]

Primary copper smelting is the largest emitter of copper. An estimate of the copper emissions from each of the primary copper smelters is presented in Table 6. This Table presents an estimate of the range of emissions, as well as, a most probable emission estimate. The range of emissions was calculated by considering the variations in both the particulate matter emitted and the composition of the particulate matter.

TABLE 6. ESTIMATED COPPER EMISSIONS - PRIMARY COPPER SMELTERS

Smelter and location	Estimated copper emissions (10^3 kg/yr)	
	Range	Most Probable
ASARCO - El Paso, TX	0.6-69	21
ASARCO - Hayden, AZ	0.8-98	23
ASARCO - Tacoma, WA	1.9-140	37
Copper Range - White Pine, MI	7.9-1000	220
Inspiration - Miami, AZ	2.0-260	60
Kennecott - Garfield, UT	3.5-460	260
Kennecott - Hayden, AZ	3.7-120	41
Kennecott - Hurley, NM	0.7-96	23
Kennecott - McGill, NV	3.5-460	130
Magma - San Manuel, AZ	2.6-1800	890
Phelps Dodge - Ajo, AZ	1.3-640	150
Phelps Dodge - Douglas, AZ	9.3-340	97
Phelps Dodge - Hidalgo, NM	1.9-190	55
Phelps Dodge - Morenci, AZ	2.4-310	74
Tennessee Copper Co. - Copperhill, TN	0.9-27	7
TOTALS	43-6000	2100

In general, the following emission estimates and compositions were used to establish the range of emissions.

Roasters

Particulate Emission Factors (Uncontrolled)

Process
Multi-hearth - 90 kg/Mg copper (Ref. 9)
Fluidized-bed - 112 kg/Mg copper (Ref. 6 Ratio)
Fugitive - 5.2 kg/Mg copper (Ref. 9)

Copper Composition of Particulate Matter

1.0% (wt.) (Ref. 10)

Particulate Control Efficiency

ESP - 96.6% (Ref. 11)

ESP + Acid Plant - 99.6% (Refs. 6 and 11)

Baghouse - 99.6% (Ref. 6)

Scrubber (Tray + Venturi) + Acid Plant - 99.9% (Ref. 6)

Scrubber + ESP + Acid Plant - 99.9% (Refs. 6 and 11)

Fugitive Hooding Capture Efficiency

Complete Enclosure - 90% (Ref. 12)

Hoods - 40% (Ref. 13)

Flash Furnace

Particulate Emission Factors (Uncontrolled)

Process - 40 kg/Mg copper (Refs. 7 and 9)

Fugitive - 0.6 kg/Mg copper (Ref. 9)

Copper Composition of Particulate Matter

0.068 - 47.4 % (wt.) (Refs. 9, 14, 15, & 16)

Particulate Control Efficiency

Spray Chamber + ESP + Acid Plant - 99.9% (Refs. 6 & 11)

ESP + Acid Plant - 99.6% (Refs. 6 & 11)

Fugitive Hooding Capture Efficiency

Hoods - 40% (Ref. 13)

Noranda Reactors

Particulate Emission Factors (Uncontrolled)

Process - 40 kg/Mg copper (Refs. 7 & 9)

Fugitive - 7.3 kg/Mg copper (Ref. 9)

Copper Composition of Particulate Matter

0.068 - 47.4% (wt.) (Ref. 9, 14, 15, & 16)

Particulate Control Efficiency

ESP's + Acid Plant - 99.9% (Refs. 6, 7, & 11)

Fugitive Hooding Capture Efficiency

Hoods - 40% (Ref. 13)

Electric Furnace

Particulate Emission Factors (Uncontrolled)

Process - 40 kg/Mg copper (Refs. 7 & 9)

Fugitive - 0.65 kg/Mg copper (Refs. 7 & 9)

Copper Composition of Particulate Matter

0.068 - 47.4% (wt.) (Refs. 9, 14, 15, & 16)

Particulate Control Efficiency

Cyclone + ESP + Acid Plant - 99.8% (Refs. 6 & 11)

Scrubber + ESP + Acid Plant - 99.9% (Refs. 6 & 11)

Fugitive Hooding Capture Efficiency

Not applicable

Reverberatory Furnace

Particulate Emission Factors (Uncontrolled)

Process - 40 kg/Mg copper (Ref. 9)

Fugitive - 0.65 kg/Mg Copper (Ref. 9)

Copper Composition of Particulate Matter

0.068 - 47.4% (wt.) (Refs. 9, 15, & 16)

Particulate Control Efficiency

ESP - 96.6% (Ref. 11)

Spray Chamber + ESP - 99.0% (Ref. 6 & 11)

ESP + Acid Plant - 99.6% (Refs. 6 & 11)

Fugitive Hooding Capture Efficiency

Hoods - 40% (Ref. 13)

Converters

Particulate Emission Factors (Uncontrolled)

Process - 120 kg/Mg Cu (Ref. 9)

Fugitive - 10 kg/Mg Cu (Ref. 9)

Copper Composition of Particulate Matter

0.15 - 19.0% (Refs. 7, 13, & 17)

Particulate Control Efficiency

Multiclones - 50% (Estimate)

ESP - 92.9% (Ref. 8)

Spray Chamber + ESP - 97.9%

Spray Chamber + ESP + Acid Plant - 99.8% (Ref. 6)

ESP + Acid Plant - 99.1% (Ref 6)

ESP + SO_2 Plant - 99.1% (Ref. 6)

ESP + Scrubber + Acid Plant - 99.9% (Ref. 6)

Fugitive Hooding Capture Efficiency

Hoods - 40% (Ref. 13)

Slag Furnace

Particulate Emission Factors (Controlled)

Process - 2.2 kg/hr (Ref. 18)

Fugitive - Not available

Copper Composition of Particulate Matter

4.0 - 10.0% (wt.) (Ref. 19)

The range of emissions also includes estimates made by using more smelter-specific data, such as stack tests and emissions compositional analyses. An example computation is shown in the Appendix. The emissions data contain estimates of both process and fugitive emissions. To arrive at the totals, all fugitive emissions were assumed to leave the enclosed area.

Tables 7 through 21 present the emissions data by stack for each smelter. The most probable emissions data from Table 6 were used in these tables.

TABLE 7. COPPER EMISSIONS BY STACK - ASARCO, EL PASO

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Roaster acid plant	31	47(E)	337	0.3
Reverberatory	252	384	363	6.7
Converter acid plant	31	42(E)	337	0.4
Roaster roof	17	175(E)	298	2.2
Reverberatory roof	15	150(E)	298	3.2
Converter roof	20	200(E)	298	8.5

(E) = Estimated

TABLE 8. COPPER EMISSIONS BY STACK - ASARCO, HAYDEN

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack (acid plants)	305	272	339	5.7
Flash furnace roof	20(E)	200(E)	298	3.4
Converter roof	20(E)	200(E)	298	14.0

(E) = Estimated

TABLE 9. COPPER EMISSIONS BY STACK - ASARCO, TACOMA

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	163	406	366	9.6
Roaster roof	20	200(E)	298	0.3
Reverberatory roof	15	150(E)	298	0.4
Converter roof	20	200(E)	298	5.4

(E) = Estimated

TABLE 10. COPPER EMISSIONS BY STACK - RANGE, WHITE PINE

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	152	182	494	200
Reverberatory roof	15(E)	150(E)	298	5.2
Converter roof	20(E)	200(E)	298(E)	16.0

(E) = Estimated

TABLE 11. COPPER EMISSIONS BY STACK - INSPIRATION, MIAMI

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	61	52	327	3.6
Electric Furnace roof	20(E)	200(E)	298	8.0
Converter roof	20(E)	200(E)	298(E)	48.0

(E) = Estimated

TABLE 12. COPPER EMISSIONS BY STACK - KENNECOTT, HAYDEN

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Acid plant	30	47	352	0.5
Reverberatory Furnace	183	61	533	13
Roaster roof	17(E)	175(E)	298(E)	2.8
Reverberatory roof	15(E)	150(E)	298	3.4
Converter roof	20(E)	200(E)	298(E)	21

(E) = Estimated

TABLE 13. COPPER EMISSIONS BY STACK - KENNECOTT, HURLEY

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Flash furnace acid plant	155	16	352	0.9
Converter acid plant	61	42	352	2.1
Old furnace stack	191	5	298	0.4
Flash furnace roof	20	200(E)	298	2.9
Converter roof	20	200(E)	298(E)	17

(E) = Estimated

TABLE 14. COPPER EMISSIONS BY STACK - KENNECOTT, MAGNA

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack (acid plant)	367	472	338	130
Reactor roof	17(E)	184	298	10.6
Converter roof	20(E)	245	298	120

(E) = Estimated

TABLE 15. COPPER EMISSIONS BY STACK - KENNECOTT, McGILL

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	229	354	423	84
Reverberatory roof	15(E)	150(E)	298(E)	2.2
Converter roof	20(E)	200(E)	298(E)	13

(E) = Estimated

TABLE 16. COPPER EMISSIONS BY STACK - MAGNA, SAN MANUEL

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	187	189	519	820
Converter acid plant #1	61	88	325	2.5
Converter acid plant #2	61	88	325	2.4
Reverberatory roof	15(E)	150(E)	298	9.4
Converter roof	20(E)	200(E)	298(E)	60

(E) = Estimated

TABLE 17. COPPER EMISSIONS BY STACK - PHELPS DODGE, AJO

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	110	83	353	57
Reverberatory roof	15(E)	150(E)	298	11
Converter roof	20(E)	200(E)	298	78

(E) = Estimated

TABLE 18. COPPER EMISSIONS BY STACK - PHELPS DODGE, DOUGLAS

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Main stack	166	137	500	17
Converter	172	112	450	30
Roaster roof	17(E)	175(E)	298(E)	13
Reverberatory roof	15(E)	150(E)	298	3.3
Converter roof	20(E)	200(E)	298(E)	34

(E) = Estimated

TABLE 19. COPPER EMISSIONS BY STACK - PHELPS DODGE, HIDALGO

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Acid plant	61	17	352	4.7
Slag furnace	183	157	401	17
Flash furnace roof	20(E)	200(E)	298	12
Converter roof	20(E)	200(E)	298	19
Slag furnace roof	20(E)	200(E)	298(E)	2.9

(E) = Estimated

TABLE 20. COPPER EMISSIONS BY STACK - PHELPS DODGE, MORENCI

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Reverberatory acid plant	184	52	353	10
Converter acid plant	184	314	353	23
Reverberatory roof	15(E)	150(E)	298	0.9
Converter roof	20(E)	200(E)	298	40

(E) = Estimated

TABLE 21. EMISSIONS BY STACK - COPPER
TENNESSEE COPPER CO., COPPERHILL

Stack	Stack height (m)	Flow (m^3/sec)	Temperature (°K)	Copper emissions (10^3 kg/yr)
Acid plant stack #1	30(E)	54	339	0.08
Acid plant stack #2	30(E)	54	339	0.07
Roaster roof	17(E)	175(E)	298(E)	0.7
Electric furnace roof	20(E)	200(E)	298(E)	0.8
Converter roof	20(E)	200(E)	298(E)	5.3

(E) = Estimated

The emissions data presented do not consider the quantity of copper which occurs as a vapor. Several testing studies have been conducted to estimate the quantity of copper in both particulate matter and vapor emissions. In one study, the results for instack/outstack particulate emissions from reverberatory furnaces were 230/1030 and 95/2335 Mg/dscm for Magna Copper and Phelps Dodge, Ajo, respectively.[11] In another study which evaluated the performance of the ESP on the reverberatory furnace at Phelps Dodge, Ajo, the efficiency of the ESP measured at a stack temperature of 315°C was 96 percent while the efficiency measured out-of-stack at 120°C was <50 percent.[9] In two studies, both conducted at Kennecott's Hayden smelter, the fraction of copper as vapor at the outlet of the reverberatory furnace ESP, varied from 0.01 to 0.05.[14,22]

The form of the copper in the emission streams has not been readily defined in most cases. For reverberatory furnaces, copper existed as hydrates of copper sulfate on the instack filter collected at the ESP outlet and as copper sulfate, copper oxide (CuO), and hydrates of copper sulfate in the dust collected by the ESP.[14]

Emissions were not estimated for refining furnaces due to a lack of data on both emission rates and compositions. One source of particulate emission data reported uncontrolled emissions of 20.0 kg/Mg and ESP controlled emissions of 0.06 kg/Mg of copper produced from refining furnaces.[23] Only one plant, ASARCO, Tacoma, has a control (ESP) on an anode furnace.[12,24]

IRON AND STEEL

Iron and steel plants are a large source of copper emissions. In this report, an estimated 112 - 240 x 10^3 kg of copper are emitted per year from

iron and steel processes. This estimate includes process and fugitive emissions from coking, sintering, blast furnaces, and the steel making furnaces. The estimate does not consider other fugitive emissions from open dust sources, such as conveyor transfer points, storage and waste piles, and paved and unpaved roads.

Some open dust sources may emit significant quantities of particles, and possibly copper. For example, one study estimated that unpaved roads in steel plants may be the source of 45,451 Mg/yr of particulate matter emissions.[25] Copper analyses performed on the emissions from unpaved roads in two steel facilities showed results of 0.0 and 0.04 percent copper.[26]

The HEM input data for the iron and steel processes are highly variable. Suggested (and estimated) inputs are summarized below.

Source	Stack height (m)	Flow (m^3/sec)	Temperature (°K)
Coke ovens	19	120	390
Sinter plants	31	280	400
Blast furnaces	31	140	330
Open hearth furnaces	31	120	500
Basic oxygen furnaces	38	170	340
Electric arc furnaces	31	60	394

Coke Ovens

During the coking of coal, particulate matter is generated. The particulate matter contains a small amount of copper (approximately 0.004 wt. percent) (Personal communication, R. C. McCrillis, EPA, August 21, 1984). Estimated copper emissions are 2.3×10^3 and 0.5×10^3 kg/yr for metallurgical and foundry coke plants, respectively. The copper emissions from individual coke plants are shown in Tables 22 and 23.

The emissions were calculated using emission factors from AP-42.[6] Comparison of the emission factors for controlled and uncontrolled particulate emissions from coke pushing shows a control efficiency of 98.8 percent for an enclosed coke car vented to a scrubber. According to an EPA source, this efficiency is probably high, and other results have shown an efficiency of less than 90 percent (Personal communication, R. C. McCrillis, EPA, August 21, 1984).

The emission calculations also assumed that the plant operated at capacity for 350 days per year. Assumed control efficiencies for the combustion stacks are 95 percent for ESP's and 99 percent for baghouses. Estimated control efficiencies for other sources are 0, 98, and 99 percent for leaks, charging, and pushing, respectively.[6]

Sinter Plants

Sinter plants make agglomerated feed for blast furnaces out of fine-grained raw materials, such as iron ore, coke breeze, fluxstone, mill scale,

Table 22 - Estimated Copper Emissions - Coking Operation

Company and location	Number of ovens	Rated capacity (Mg/day)	Oven height (m)	Type control-pushing[A]	Type control-combustion stacks[A]	Estimated copper emissions (10^3 kg/yr)[B]
ARMCO, INC.						
Hamilton, OH	110	1751	4	Granite City car with scrubber	ESP	0.02
Houston, TX	62	948	4	Shed with common ESP (wet)	ESP	0.01
Middletown, OH	71	4672	4	Land-base baghouse		
	114		6	Dravo-Osterfield cars with scrubber		0.07
BETHLEHEM STEEL						
Bethlehem, Pa	408		3	Envirotech/Chemico H-II		
	80	5298	4	Envirotech/Chemico H-II		0.08
	80		6	Bench-mounted hood, fixed duct, venturi scrubbers		
Burns Harbor, IN	164	6051	6	Bench-mounted hood, fixed duct, venturi scrubbers		0.09
Johnstown, PA	77	3175	4	Koppers/Rosedale car with scrubber		
Lackawanna, NY	152	7385	4	Envirotech/Chemico H-II		0.05
	76		6			
Sparrows Pt., MD	130		4	Envirotech/Chemico H-II		0.14
	63	4990	6	Land-based system		0.14
	312			None		
ROUGE STEEL	205	3937	5[C]	Koppers/Ford bench, mounted hood, fixed duct/scrubbers	ESP	0.04
INLAND STEEL						
Indiana Har., IN	266	5597	4	Granite City/scrubber	ESP	0.12
	51		6	Granite City car		
	56	2268	6	Shed with scrubber	ESP	
	69	2734	6	Koppers one-spot		
INTERLAKE						
Chicago, IL	100	1579	4	Minister Stein with scrubber		0.02
LTV (J&L)						
Aliquippa, PA	106	3908	4	No control reported		0.09
	56		6	Shed with venturi scrubber		
Campbell, OH	152	3629	5[C]	None		0.10
INd. Harbor, IN	162	3674	4	Envirotech/Chemico H-III		0.05
Pittsburgh, PA	315	4808	4	Minister Stein		0.07
LONE STAR STEEL						
Lone Star, TX	70	1089	5	Koppers/Lone Star scrubber	ESP	0.01

TABLE 22 (continued).

Company and location	Number of ovens	Rated capacity (Mg/day)	Oven height (m)	Type control-pushing[A]	Type control-combustion stacks[A]	Estimated copper emissions (10^3 kg/yr)[B]
NATIONAL STEEL						
Great Lakes, MI	148	2,268	4	Mitsubishi bench-mounted, hood fixed, duct to scrubber		0.07
	85	2,631	6	Same as Batteries 3, 4		
Granite City, IL	45	726	4-5	Granite City one-spot with scrubber	ESP	0.01
Weirton, WV	87	3,266	6	Koppers one-spot with scrubber		0.09
	41	2,041	4	TSQ with scrubber		
	61		4	None		
LTV (Republic)						
Chicago, IL	?	1,633	6	Mitsubishi bench-mounted Hood with wet ESP		0.02
Cleveland, OH	204	2,524	4	Koppers/Rosedale one-spot with scrubber		0.06
	126	1,773	4	Envirotech/Chemico H-III		
Gadsden, AL	130	2,152	4	No controls		0.06
Massillon, OH	31	523	4	No controls		0.01
Warren, OH	85	1,680	4	Envirotech/Chemico H-III		0.02
Youngstown, OH	162	2,694	4	Envirotech/Chemico H-III		0.04
U.S. STEEL						
Clairton, PA	192		4	Envirotech/Chemico H-III		
	192		4	Envirotech/Chemico H-III		
	61		4	Envirotech/Chemico H-III		0.27
	61	18,933	4	Shed with scrubber		
	174		5	Envirotech/Chemico H-III		
	174		5	Envirotech/Chemico H-III	ESP	
Fairfield, AL	63		4	Mitsubishi bench-mounted hood, fixed duct with baghouse		0.09
	57	6,229	6	U.S. steel one-spot care with scrubber		
Fairless, PA	174	2722	4	Sheds with baghouse		0.04
Gary, IN	199		6	U.S. Steel one-spot car with scrubber		0.16
	154	10,850	3	Mitsubishi bench-mounted hood/ fixed duct with baghouse		
	154		3	Mitsubishi system planned		
Lorain, OH	413	4,053	3	Shed with baghouse		0.06
Geneva, UT	252	4,536	3	Sheds with baghouse		0.07
WHEELING/PIT.						
Monessen, PA	56	1,666	3	Minister Stein with baghouse		0.02
Steubenville,	145	4,722	3	Sheds with bag (committed)		
	79		6	Bench-mounted hood-fixed duct with scrubber		0.07
					TOTAL	2.3

A Assumed control efficiency of 95% for ESP and 99% for BH.
B Based on 350 days/yr operating time, using particulate emission factors from Reference 6, includes charging, door leaks, pushing, quenching, and combustion stacks. Copper wt. % figures from Reference 27, are 0.004 wt. % for everything but door leaks (0.0036 wt. %).
C Estimated

Table 23. Estimated Copper Emissions - Foundry Coke Plants

Company and location	Number of ovens	Rated capacity (Mg/day)	Oven height (M)	Type control-pushing	Estimated copper emissions (10^3 kg/yr)
ALABAMA, B-P Tarrant, AL	130	2177	4A	Hawley trav. hood with land baghouse	0.03
ALLIED CHEMICAL ASHLAND, KY	146	3157	4	Minister Stein with scrubber	0.05
CARONDELET COKE St. Louis, MO	93	907	3	Shed with baghouse	0.01
CHATT. COKE Chattanooga, TN	44	523	4	Hawley trav. hood with baghouse	0.01
CITIZ. GAS Indianapolis, IN	160	2477	4-5	Hawley trav. hood with baghouse	0.04
DETROIT COKE Detroit, MI	70	1950	5	Minister Stein with baghouse	0.03
DONNER-HANNA Buffalo, NY	51 100	2725	4 4	Pect/D.H. spray system No controls	0.06
EMPIRE COKE Holt, AL	60	327	3	No controls	0.01
MERGLER CORP. Erie Coke Painesville, OH	46	408	4	Shed with baghouse	0.01
INDIANA GAS Perre Haute, IN	60	363	4	Hawley trav. hood with scrubber	0.01
IRONTON COKE Ironton, OH	92	2404	4	Mitsubishi bench-mounted hood, fixed duct with baghouse	0.03
JIM WALTER RES. Birmingham, AL	120	2504	4-5	Hawley trav. hood (committed)	0.04
KOPPERS CO., INC. Erie, PA Toledo, OH Woodward, AL	58 57 226	635 738 1857	4 4 4	Koppers-Erie car with scrubber Koppers one-spot with scrubber Koppers one-spot with scrubber	0.01 0.01 0.03
MILWAUKEE, SOLVAY Milwaukee, WI	100	726	3	Mitsubishi bench-mounted hood, fixed duct with scrubber	0.01
PHILADELPHIA COKE Philadelphia, PA	74	853	4	Hawley trav. hood with scrubber	0.01
TONAWANDA COKE TONAWANDA, NY	60	1624	4	No controls	0.05
				TOTAL	0.45

A Estimated

and flue dust. Particles are emitted from two major points on a sinter machine; the windbox and the discharge (breaker and screens). Copper is a component of the particle emissions. One reference states that copper is present at the 0.104 percent (wt.) level.[27]

Estimated copper emissions from each of the operating sinter plants are shown in Table 24. Actual production rates were not available for these plants. Therefore, the rated capacity was used in the calculations. The operation time of the plants was estimated to be 300 days/year (Personal communication, R. C. McCrillis, EPA, August 21, 1984).

Blast Furnaces

Blast furnaces produce iron for the steel-making furnaces. The offgas from the blast furnace is treated for the removal of particles and is then used as a fuel within the steel plant. Emissions have been defined from three sources; the cast house, the tap hole and trough, and blast furnace slips (i.e., the bridging of the furnace charge and the subsequent collapse of the charge).

Estimated controlled copper emissions from blast furnaces are shown in Table 25. Capacities and 1980 production figures were taken from several sources.[28,29,30] The emission figures include the cast house emissions and the emissions from the tap hole and trough.[31] The low and high numbers are the result of two copper analyses, 0.051 and 0.5 percent (wt).[32,33]

Blast furnace slips occur infrequently and only on some furnaces. Slips can occur as a result of the type of furnace charge or furnace operating conditions. A study conducted in 1976, estimated 4 to 9 slips per blast furnace month from blast furnaces in Allegheny County, Pennsylvania.[34] This same study estimated particle emissions of 0.0025 - 0.023 kg per Mg hot metal for a nationwide total of 170 to 1700 kg of emissions.[34]

Due to the infrequency of slips and the uncertainty of which furnaces produce slips, the emissions from slips were not included in the totals for each blast furnace in Table 25. However, total copper emissions of 0.1×10^3 to 9.2×10^3 kg/yr could be expected from slips.

Open Hearth Furnaces

The use of open hearth furnaces to produce steel has declined over the last decade.[28,29] Even with this decline, some steel companies have continued to operate open hearths because of the furnace's capability to melt scrap. In 1980, seventy-seven open hearth furnaces were being operated at twelve steel plants.[28]

The copper content of open-hearth emissions range from 0.14 - 0.19 percent (wt.) of the total particulate matter emissions.[35,36] Uncontrolled particulate matter emissions vary from 6.25 - 10.55 kg/Mg of steel produced.[31,35] Total estimated copper emissions are 2.1×10^3 - 3.5×10^3 kg/yr. Estimated copper emissions by source are shown in Table 26.

Table 24. Estimated Copper Emissions - Sinter Plants

Company and facilities	Rated capacity (Mg/day)	Windbox control[A]	Discharge control[B]	Estimated copper emissions (10^3 kg/yr)[C]
ARMCO, INC.				
Ashland, KY	2,268	Flooded disc scrubber	E	0.2
Houston, TX	1,270	Steam-hydro scrubber	Baghouse	0.1
Middletown, OH	2,395	Venturi scrubber	Baghouse	0.2
BETHLEHEM STEEL				
Bethlehem, PA	5,534	Venturi scrubber	Baghouse	0.5
Burns Harbor, IN	5,443	Wet ESP's	Baghouse	0.3
Lackawanna, NY	3,629	Wet ESP's	Scrubbers	0.4
Sparrows Pt., MD	10,886	Venturi scrubbers	Baghouse	1.0
INLAND STEEL				
Indiana Har., IN	3,629	Multiclones, dry ESP, baghouse in series	Baghouse	0.2
LTV (J&L)				
Ind. Harbor, IN	3,629	Multiclones, dry ESP, venturi scrubber in series	Venturi scrubber	0.2
NATIONAL STEEL				
Great Lakes, MI	4,355	Gravel bed filter	Multiclones	8.2
Granite City, IL	2,722	Cyclones, venturi scrub.	Baghouse	0.2
Weirton, WV	4,536	Gravel bed filter	Rotoclone[F]	1.2
LTV (Republic)				
Gadsden, AL	1,588	Cyclone, Baghouse	Cyclones, Baghouse	0.1
Warren, OH	544	Multiclone	E	0.1
Youngstown, OH	4,536	ESP	Cyclone	5.4
U.S. STEEL				
So. Chicago, IL	4,536	Cyclone, ESP EDV scrubber (series)	Baghouse	0.2
Fairfield, AL	7,076	Dry ESP	Baghouse	1.9
Fairless, PA	6,623	Cyclones	Rotoclones	7.2
Gary, IN	4,536	ESP[D]	Baghouse	1.2
	4,536	ESP[D]	Baghouse	1.2
	4,536	ESP[D]	Baghouse	1.2
Geneva, UT	2,722	Scrubber	Rotoclone	2.7
Saxonburg, PA	12,701	ESP[D]	Baghouse	3.4
	12,701	ESP[D]	Baghouse	3.4
WHEELING/PIT.				
Monessen, PA	907	Wet ESP	Scrubber	0.1
Steubenville, OH	1,361	Venturi scrubbers	Baghouse	0.1
			TOTAL	41

A Estimated control efficiencies - wet ESP 98%; dry ESP 86%, scrubber 96%; cyclones 91%.
B Estimated control efficiencies - baghouse, 98%; scrubbers 91%; cyclones 90%.
C Cu Emissions - Assumption - Sinter plant operates 300 days/yr, Cu content = 0.104 wt.% 27.
D Assumed dry ESP.
E Assumed baghouse control (Ref. R. C. McCrillis, EPA, October 31, 1984).
F Personal observation (R. C. McCrillis, EPA).

TABLE 25. ESTIMATED COPPER EMISSIONS - BLAST FURNACES[29,30,31]

Company and plant location	Estimated capacity (Mg/day)	No. of furnaces operating (1980)	Estimated production 1980 (10^6 Mg/yr)	Estimated copper emissions (10^3kg/yr)* Low	High
ARMCO, Inc.					
Ashland, KY	5,080	2	1.3	0.30	2.9
Middletown, OH (Hamilton)	1,052	1	0.3	0.07	0.7
Middletown, OH	4,291	1	1.1	0.25	2.5
Houston, TX	1,996	1	0.5	0.11	1.1
Bethlehem Steel					
Bethlehem, PA	9,616	4	2.4	0.55	5.4
Burns Harbor, IN	4,990	2	1.3	0.30	2.9
Johnstown, PA	4,717	2	1.2	0.28	2.7
Lackawanna, NY	8,709	4	2.2	0.50	5.0
Sparrows Point, MD	15,424	4	3.9	0.89	8.8
Crucible, Inc.					
Midland, PA	1,814	4	0.5	0.11	1.1
Inland Steel					
East Chicago, IL	26,490	9	6.7	1.54	15
Interlake, Inc.					
S. Chicago, IL	3,084	2	0.8	0.18	1.8
LTV					
Aliquippa, PA	8,165	3	2.1	0.48	4.7
Buffalo, NY	2,858	2	0.7	0.16	1.6
Cleveland, OH (J&L)	4,869	2	1.2	0.28	2.7
Cleveland, OH (Rep.)	7,705	5	2.0	0.46	4.5
Gadsden, AL	2,087	2	0.5	0.11	1.1
Indiana Harbor, IN	9,707	4	2.5	0.57	5.6
S. Chicago, IL	2,604	1	0.7	0.16	1.6
Warren, OH	2,540	1	0.6	0.14	1.4
Youngstown, OH	2,286	2	0.6	0.14	1.4
Mclouth Steel					
Trenton, MI	4,536	2	1.2	0.28	2.7
National Steel					
Granite City, IL	4,717	2	1.2	0.28	2.7
Ecorse, MI	9,117	4	2.3	0.53	5.2
Buffalo, NY	1,950	3	0.5	0.11	1.3
Rouge Steel Co. (Ford)					
Dearborn, MI	5,944	3	1.5	0.34	3.4
Sharon Steel					
Sharon, PA	2,540	2	0.6	0.14	1.4
U.S. Steel					
Braddock, PA	6,985	4	1.8	0.41	4.1
Fairless, PA	7,444	3	1.9	0.44	4.3
Rankin, PA (Homestead)	5,912**	4	1.5	0.34	3.4

TABLE 25 (continued)

Company and plant location	Estimated capacity (Mg/day)	No. of furnaces operating (1980)	Estimated production 1980 (10^6 Mg/yr)	Estimated copper emissions (10^3kg/yr)* Low	High
Lorain, OH	5,327**	4	1.4	0.32	3.2
McKeesport, PA	998	1	0.3	0.07	0.7
Duquesne, PA	4,763	3	1.2	0.28	2.7
Gary, IN	15,048	7	3.8	0.87	8.6
S. Chicago, IL	6,996	4	1.8	0.41	4.1
Geneva, UT	5,171	3	1.3	0.30	2.9
Fairfield, AL	4,572	3	1.2	0.28	2.7
Wheeling Pittsburg Stubensville, OH	6,623	5	1.7	0.39	3.8
Monessen, PA	3,992	3	1.0	0.23	2.3
Weirton Steel Weirton, WV	8,800	4	2.2	0.50	5.0
Wisconsin Steel (WSC Corp) S. Chicago, IL	2,177	3 (2?)	0.6	0.14	1.4
Total (Furnace)				14	140
Total (Slips)				0.1	9.2
Total				14	150

*Emission Factor = 0.3 + 0.15 kg/Mg cast house, tap hole, and trough.[31]
Cu = 0.051 - 0.500% (wt.)
**1976 Production[30]

Basic Oxygen Furnaces

Two major types of basic oxygen furnaces are currently used in the U.S. steel industry. Fifty-eight of the sixty-six BOF's in the U.S. are the conventional top-blown furnaces, while eight are bottom-blown or QBOP furnaces. Most furnaces are equipped with hoods, either closed or open, which collect the furnace emissions and direct them to either an ESP or a scrubber. In addition to these emissions, fugitive emissions are generated during the furnace charging and hot-metal tapping.

Estimated copper emissions from basic oxygen furnaces are shown in Table 27. The list of furnaces and the annual capacity were obtained from reference 37. The 1983 production was estimated by using a capacity utilization factor of 67.3 percent. This factor was calculated by dividing the 1983 steel production in BOF's by the capacity obtained from reference 37. Control device information was obtained from references 29 and 38.

Many tests were performed on BOF's during the development of the NSPS.[39] These test results were used to calculate yearly, controlled particulate emissions. Copper emissions were estimated by using a copper content of 0.03 - 0.04 percent (wt.).[36]

TABLE 26. ESTIMATED COPPER EMISSIONS - OPEN HEARTH FURNACES[A]

Company and plant location	No. of furnaces	Annual capacity[B] (10^6 Mg/yr)	Estimated 1983 production[C] (10^6 Mg/yr)	Control device	Estimated particulate emissions[G] (10^6 kg/yr) Fugitive	Process	Estimated copper emissions[H] (10^3 kg/yr)
ARMCO Inc.							
Middletown, OH	6	1.11	0.80	WS[D]	0.07	0.50 - 0.84	0.8 - 1.7
Bethlehem Steel							
Johnstown, PA	6	0.11(E)	0.08	E	0.01	0.01	0.03 - 0.04
Sparrows Point, MD	7	0.27(E)	0.19	E	0.02	0.03	0.07 - 0.10
MD							
Inland Steel							
East Chicago, IN	7	2.22	1.59	ESP	0.13	0.22 - 0.24	0.49 - 0.70
Lone Star Steel							
Lone Star, TX	5	0.91	0.65	F	0.05	0.01	0.08 - 0.11
LTV							
East Chicago, IN	8	1.60(E)	1.15	E	0.10	0.16 - 0.17	0.36 - 0.51
Mesta Machine Co.							
W. Homestead, PA	4	0.22(E)	0.16	E	0.01	0.02	0.04 - 0.06
Phoenix Steel							
Phoenixville, PA	2	0.19(E)	0.14	E	0.01	0.02	0.04 - 0.06
United States Steel							
Fairless, PA	9	0.25(E)	0.18	E	0.02	0.03	0.07 - 0.10
Homestead, PA	11	0.20(E)	0.14	E	0.01	0.02	0.04 - 0.06
Gary, IN	2	0.02(E)	0.01	E	-		Neg.
Geneva, UT	10	0.22(E)	0.16	E	0.01	0.02	0.04 - 0.06
	77						2.1 - 3.5

A List of furnaces derived from Reference 29 and updated to 1980 by Reference 28.
B Extracted from Reference 29. (E) indicates estimate made by multiplying total heat size by 700 heats/year (average of data on annual capacity ÷ heat size).
C Production estimated by using 71.7% capacity. This number was derived by dividing the 1983 production by the total estimated annual capacity (derived by B).
D Assumed 90% control efficiency.
E Assumed ESP controlled (Personal Communication, R. C. McCrillis, EPA).
F Steam-hydro air cleaning system, 99.9% efficiency (Ref. 40).
G Emission factors - uncontrolled = 6.25 - 10.55 kg/Mg[31,35]; ESP controlled 0.14 - 0.15 kg/Mg.[31,35]
H Copper values = 0.14 - 0.19 wt. %.[35,36]

TABLE 27. ESTIMATED COPPER EMISSIONS - BOF AND QBOP FURNACES

Company and plant location	No. of furnaces	Annual capacity (10^6 Mg/yr)[B]	Estimated 1983 production (10^6 Mg/yr)	Control device[C]	Estimated particulate emissions[E] (10^6 kg/yr)		Estimated copper emissions (10^3 kg/yr)
					Fugitives[D]	Process	
Allegheny Ludlum Steel Corp.							
Brackenridge, PA	2	0.5	0.3	S	0.1	0.002	0.03
Armco Inc.							
Ashland, KY	2	1.9	1.3	ESP	0.6	0.02	0.22
Middletown, OH	2	2.0	1.3	SC	0.6	0.01	0.21
Bethlehem Steel Corp.							
Sparrows Point, MD	2	2.9	2.0	S	0.9	0.02	0.32
Bethlehem, PA	2	2.7	1.8	ESP	0.8	0.02	0.29
Burns Harbor, IN	3	4.8	3.2	S	1.5	0.03	0.54
Inland Steel Co.							
East Chicago, IN	4	5.5	3.7	SC	1.7	0.03	0.61
Interlake Inc.							
Chicago, IL	2	1.0	0.7	ESP	0.3	0.01	0.11
LTV Steel Corp.							
Aliquippa, PA	3	3.2	2.2	ESP	1.0	0.03	0.36
Cleveland, OH	2	2.6	1.7	ESP	0.8	0.02	0.29
East Chicago, IN	2	3.2	2.2	ESP	1.0	0.03	0.36
Warren, OH	2	2.3	1.5	ESP	0.7	0.02	0.25
Gadsen, AL	2	1.4	0.9	ESP	0.4	0.01	0.14
Cleveland, OH	2	2.5	1.7	ESP	0.8	0.02	0.29
Chicago, IL	2[A]	1.1	0.7	S	0.6	0.01	0.21
McLouth Steel Products Corp.							
Trenton, MI	5	2.5	1.7	S	0.8	0.01	0.28
National Steel Corp.							
Great Lakes Steel Div.							
Ecorse, MI	2	2.4	1.6	ESP	0.7	0.02	0.25
Granite City Steel Co.							
Granite City, IL	2	2.1	1.4	ESP	0.6	0.02	0.22
Rouge Steel Co.							
Dearborn, MI	2	2.6	1.7	ESP	0.8	0.02	0.29
Sharon Steel Corp.							
Farrell, PA	2	1.4	0.9	S	0.4	0.01	0.14

(continued)

TABLE 27 (continued)

Company and plant location	No. of furnaces	Annual capacity (10^6 Mg/yr)[B]	Estimated 1983 production (10^6 Mg/yr)	Control device[C]	Estimated particulate emissions[E] (10^6 kg/yr) Fugitives[D]	Process	Estimated copper emissions[F] (10^3 kg/yr)
U.S. Steel Corp.							
Fairfield, AL	3[A]	2.7	1.8	SO	1.6	0.01	0.56
Gary, IN	3	3.6	2.4	SO	1.1	0.02	0.39
	3[A]	2.7	1.8	SO	1.6	0.01	0.56
Lorain, OH	2	2.5	1.7	SO	0.8	0.003	0.28
Braddock, PA	2	2.5	1.7	SV	0.8	0.01	0.28
Weirton Steel Corp.[4]							
Weirton, WV	2	3.5	2.4	SV	1.1	0.02	0.39
Wheeling-Pittsburgh Steel Corp							
Monessen, PA	2	1.6	1.1	ESP	0.5	0.01	0.18
Steubenville, OH	2	2.4	1.6	SV	0.7	0.01	0.25
Totals	66						8.3

A QBOP Furnaces

B Production estimated by using a capacity utilization factor of 67.3%. Factor calculated by dividing production by capacity.

C Control device codes are N = none or unknown; S = scrubber, unidentified hood; SC = scrubber with closed hood; SV = venturi; SO = scrubber with open hood; ESP = electrostatic precipitators

D All fugitive (secondary) emissions are assumed to be uncontrolled, due to a lack of information on each plant.

E Particulate emissions estimated using data from test reports.

F Estimated copper content of 0.035 (wt.) percent.[37]

Electric Arc Furnaces

Electric arc furnaces (EAF's) are used to make carbon and alloy steels with a charge which consists of mostly scrap. Hundreds of electric arc furnaces are operating in the major steel mills and in the small specialty shops (mini- and midi-mills). Most of these furnaces, especially those in small shops, are controlled with baghouses. Wet scrubblers and ESP's are also used.

Estimated copper emissions are shown in Tables 28 through 30. Three tables have been used because the data were taken from different sources, and the emission calculations varied slightly.

For Table 28, the estimated annual capacity[31] was multiplied by a capacity utilization factor of 50.8 percent. This factor was obtained by dividing the total EAF capacity[41] by the 1983 steel production in EAF's. Estimated uncontrolled particulate emissions were calculated using an emission factor range of 7.5 to 20.0 kg/Mg.[6,32,42] Fugitive emissions (uncontrolled) were calculated using an emission factor of 0.9 kg/Mg.[42] Copper emissions were calculated using 0.265 percent (wt.) copper content.[43]

For Table 29, the capacity was estimated by multiplying the average hourly production by 8760 hours per year.[29] Production was then estimated by using the capacity utilization factor of 50.8 percent. The same emission factors described above were used to calculate the emissions.

Estimated emissions from mini- and midi-mills are shown in Table 30. Company data, capacities, types of control devices, and number of furnaces were obtained from reference 44. Production was estimated by using the 50.8 percent capacity utilization factor. Emissions estimates used the above stated factors.

Another list of electric arc furnaces is shown in Table 31.[42] Data on capacities and production could not be found on these furnaces. Therefore, emissions could not be estimated.

TABLE 28. ESTIMATED COPPER EMISSIONS - ELECTRIC ARC FURNACES

Company and plant location	Annual capacity (10^6 Mg/yr)	Estimated 1983 production (10^6 Mg/yr)	Control device[B]	Estimated particulate emissions (10^6 kg/yr)[D,E]		Estimated copper emissions[F] (10^3 kg/yr)
				Fugitives[D]	Process	
ARMCO						
Butter, PA	0.83	0.42	WS	0.4	0.32 - 0.84	1.9 - 3.3
Houston, TX	1.66	0.84	WS/BH[C]	0.8	0.26 - 0.69	2.8 - 3.9
LTV						
Cleveland, OH	0.75	0.38	ESP	0.3	0.17 - 0.46	1.2 - 2.0
Lone Star Steel						
Lone Star, TX	0.30	0.15	BH	0.1	0.01 - 0.02	0.3
McLouth Steel Corp.						
Trenton, MI	0.38	0.19	WS	0.2	0.14 - 0.38	0.9 - 1.5
National Steel Corp.						
Ecorse, MI	0.63[A]	0.32	BH	0.3	0.01 - 0.03	0.8 - 0.9
Northwestern Steel & Wire Co.						
Sterling, IL	1.82	0.92	BH, WS	0.8	0.03 - 0.06	2.2 - 2.4
U.S. Steel						
Baytown, TX	0.52	0.26	BH	0.2	0.01 - 0.03	0.6
Fairless Hills, PA	0.53	0.27	BH	0.2	0.01 - 0.03	0.6
S. Chicago, IL	0.81	0.41	BH	0.4	0.02 - 0.04	1.1 - 1.2 / 12 - 16

A Based on 1976 production (Reference 30).
B Control device codes - WS = wet scrubber; BH = baghouse.
C BH on 62% of production; WS on 38%.
D Estimated control efficiences - BH 99.5%; WS 90.0%; ESP 94.0%
E Uncontrolled process emission factor = 7.5 - 20 kg/Mg; fugitive = 0.9 kg/mg.[41]
F Copper content 0.265 wt. % Cu.

TABLE 29. ESTIMATED COPPER EMISSIONS - ELECTRIC ARC FURNACES (Capacity Estimated)

Company and plant location	Estimated capacity[A] (10^6 Mg/yr)	Estimated 1983 production[B] (10^6 Mg/yr)	Control device	Estimated fugitive emissions[D] (10^6 kg/yr)	Estimated controlled particulate emissions[E,F] (10^6 kg/yr)	Estimated copper emissions[F,G] (10^3 kg/yr)
Al Tech Specialty Steel Corp.						
Watervliet, NY	0.06	0.03	BH	0.03	0.03 - 0.03	0.1
Armco, Inc.						
Baltimore, MD	0.33	0.17	*	0.15	0.16 - 0.17	1.2[H]
Torrance, CA	0.06	0.03	BH[C]	0.03	0.16 - 0.37	0.4 - 1.0
Cameron Iron Works						
Houston, TX	0.19	0.10	*	0.09	0.09 - 0.10	0.2 - 0.3
Colt Industries (Crucible)						
Syracuse, NY	0.09	0.05	*	0.05	0.05 - 0.06	0.1 - 0.2
Columbia Tool Steel Co.						
Chicago Heights, IL	0.02	0.01	*	0.01	0.01	Neg.
Conners Steel Co.						
Birmingham, AL	0.24	0.12	BH	0.11	0.11 - 0.12	0.3
Huntleyton, WV	0.13	0.07	*	0.06	0.06 - 0.07	0.2
Copperweld Steel Co.						
Warren, OH	0.16	0.08	*	0.07	0.07 - 0.08	0.2
Cyclops Corp.						
Mansfield, OH	0.22	0.11	*	0.10	0.10 - 0.11	0.3
Bridgeville, PA	0.10	0.05	BH	0.05	0.05 - 0.06	0.1 - 0.2
Edgewater Steel Corp.						
Oakmont, PA	0.09	0.05	*	0.05	0.05 - 0.06	0.1 - 0.2
Finkl and Sons Co.						
Chicago, IL	0.10	0.05	BH	0.05	0.05 - 0.06	0.1 - 0.2
Inland Steel Co.						
East Chicago, IN	0.27	0.14	BH	0.13	0.14 - 0.14	0.4
Interlake, Inc.						
Gallatin, TN	0.26	0.13	*	0.12	0.12 - 0.13	0.3
LTV (J&L)						
Warren, MI	0.33	0.17	BH	0.15	0.16 - 0.17	0.4

(continued)

TABLE 29 (continued)

Company and plant location	Estimated capacity[A] (10^6 Mg/yr)	Estimated 1983 production[B] (10^6 Mg/yr)	Control device	Estimated fugitive emissions[D] (10^6 kg/yr)	Estimated controlled particulate emissions [E,F] (10^6 kg/yr)	Estimated copper emissions[F], (10^3 kg/yr)
Earle M. Jorgensen Co. Seattle, WA	0.07	0.04	*	0.04	0.04	0.1
Joslyn Stainless Steels Fort Wayne, IN	0.18	0.09	BH	0.08	0.08 - 0.09	0.6[H]
Keystone Consolidated Ind. Inc. Peoria, IL	0.71	0.36	BH	0.32	0.32 - 0.36	0.8 - 0.9
Georgetown Texas Steel Beaumont, TX	0.71	0.36	*	0.32	0.33 - 0.36	0.9 - 1.0
Latrobe Steel Co. Latrobe, PA	0.09	0.05	*	0.05	0.05 - 0.06	1.0 - 0.2
National Forge Co. Erie, PA	0.26	0.13	BH	0.12	0.13 - 0.13	0.3
Irvine, PA	0.10	0.05	BH	0.05	0.05 - 0.06	0.1 - 0.2
Penn-Dixie Steel Corp. Kokomo, IN	0.63	0.32	BH	0.29	0.30 - 0.32	0.8
Rouge Steel Co. Dearborn, MI	0.38	0.19	BH	0.17	0.18 - 0.19	0.5
Washington Steel Co. Houston, PA	0.08	0.04	BH	0.04	0.04 - 0.04	0.3[H]
						8.9 - 10

A Capacity estimated by using average hourly production (Ref. 29)
B Production estimated by using 50.8% capacity utilization figure
C BH control of 44.3% of production (Ref. 29)
D E.F. of 0.9 kg/Mg (Ref. 42)
E Low E.F. of 7.5 kg/Mg (Ref. 42) Assumed control eff. for BH = 99.5%
high E.F. of 20 kg/Mg (Ref. 42)
F Includes fugitive emissions
G Cu wt. % 0.265[43]
H Cu wt. % 0.72 (stainless steel)[43]
* Assumed baghouse conntrol (Ref. - R. C. McCrillis, EPA, Nov. 1984)

TABLE 30. ESTIMATED COPPER EMISSIONS - ELECTRIC ARC FURNACES (MINI & MIDI MILLS)

Company and plant location	Capacity[44] (10^6 Mg/yr)	Estimated production @ 50.8% (10^6 Mg/yr)	Control device[44]	No. of furnaces[44]	Fugitive emissions (10^6 kg/yr)	Estimated controlled particulate emissions[A] (10^6 kg/yr)	Estimated copper emissions (10^3 kg/yr)
Atlantic Steel Co.							
Atlanta, GA	0.45	0.23	BH	2	0.2	0.21 - 0.22	0.6 - 0.6
Cartersville, GA	0.27	0.14	BH	1	0.1	0.11 - 0.11	0.3 - 0.3
Auburn Steel Co.							
Auburn, NY	0.23	0.12	BH	1	0.1	0.11 - 0.11	0.3 - 0.3
Bayou Steel Corp.							
La Place, LA	0.59	0.30	BH	2	0.3	0.31 - 0.33	0.8 - 0.9
Birmingham Bolt Co.							
Illinois Steel Div.							
Kankakee, IL	0.09	0.05	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
So. United Steel Div.							
Birmingham, AL	0.11	0.06	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Border Steel Mills, Inc.							
El Paso, TX	0.19	0.10	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
B&W Steel Co.							
Calumet Steel Co.							
Chicago Heights, IL	0.14	0.07	BH	2	0.1	0.10 - 0..11	0.3 - 0.3
Cascade Steel Rolling Mills							
McMinnville, OR	0.23	0.12	*	2	0.1	0.10 - 0.11	0.3 - 0.3
Chaparral Steel Co.							
Midlothian, TX	1.27	0.65	BH	2	0.6	0.62 - 0.67	1.6 - 1.8
Charter Electric Melting, Inc.							
Chicago, IL	0.12	0.06	*	1	0.1	0.10 - 0.11	0.3 - 0.3

(continued)

TABLE 30 (continued)

Company and plant location	Capacity[44] (10^6 Mg/yr)	Estimated production @ 50.8% (10^6 Mg/yr)	Control device[44]	No. of furnaces[44]	Fugitive emissions (10^6 kg/yr)	Estimated controlled particulate emissions[A] (10^6 kg/yr)	Estimated copper emissions (10^3 kg/yr)
Florida Steel Co.							
Charlotte, NC	0.25	0.13	BH	2	0.1	0.11 - 0.11	0.3 - 0.3
Indiantown, FL	0.20	0.10	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Jackson, TN	0.36	0.19	BH	1	0.2	0.21 - 0.22	0.6 - 0.6
Jacksonville, FL	0.36	0.19	BH	1	0.2	0.21 - 0.22	0.6 - 0.6
Tampa, FL	0.25	0.13	BH	2	0.1	0.11 - 0.11	0.3 - 0.3
Georgetown Steel Corp.							
Georgetown, SC	0.54	0.27	*	2	0.2	0.21 - 0.23	0.6 - 0.6
Hawaiian Western Steel, Ltd.							
Ewa, HI	0.05	0.03	*	1	0.1	0.10	0.3 - 0.3
Hurricane Industries, Inc.							
Sealy, TX	0.09	0.05	*	1	0.1	0.10 - 0.11	0.3 - 0.3
Industrial Siderurgica							
Bayamon, PR	0.11	0.06	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Ingersoll Johnson Steel Co.							
New Castle, IN	0.03	0.02	*	4	0.1	0.10	0.3 - 0.3
Intercoastal Steel Corp.							
Chesapeake, VA	0.11	0.06	CY+BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Judson Steel Corp.	0.12	0.06	BH	1	0.1	0.10 - 0.11	0.3 - 0.3
Emeryville, CA							

(continued)

TABLE 30 (continued)

Company and plant location	Capacity[44] (10^6 Mg/yr)	Estimated production @ 50.8% (10^6 Mg/yr)	Control device[44]	No. of furnaces[44]	Fugitive emissions (10^6 kg/yr)	Estimated controlled particulate emissions[A] (10^6 kg/yr)	Estimated copper emissions (10^3 kg/yr)
Kentucky Electric Steel Co.							
Ashland, KY	0.25	0.13	BH	2	0.1	0.11 - 0.11	0.3 - 0.3
Knoxville Iron Co. (Div. of Azcon corp.)							
Knoxville, TN	0.20	0.10	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Marathon LeTourneau Co.							
Longview Div.							
Longview, TX	0.07	0.04	*	2	0.1	0.10	0.3 - 0.3
Marathon Steel Co.							
Tempe, AZ	0.17	0.09	BH	3	0.1	0.10 - 0.11	0.3 - 0.3
Milton Mfg. Co.							
Milton, PA	0.18	0.09	*	3	0.1	0.10 - 0.11	0.3 - 0.3
Mississippi Steel Div. of Magna Corp.							
Jackson, MS	0.12	0.06	BH	1	0.1	0.10 - 0.11	0.3 - 0.3
New Jersey Steel Corp.							
Sayerville, NJ	0.25	0.13	BH	1	0.1	0.11 - 0.11	0.3 - 0.3
Newport Steel Corp.							
Newport, KY	0.50	0.25	BH	3	0.2	0.21 - 0.23	0.6 - 0.6
North Star Steel Co.							
Beaumont, TX	0.91	0.46	BH	2	0.4	0.42 - 0.45	1.1 - 1.2
Monroe, MI	0.54	0.27	BH	1	0.2	0.21 - 0.23	0.6 - 0.6
St. Paul, MN	0.36	0.18	BH	2	0.2	0.21 - 0.22	0.6 - 0.6
Wilton, IA	0.27	0.14	BH	1	0.1	0.11 - 0.11	0.3 - 0.3

(continued)

TABLE 30 (continued)

Company and plant location	Capacity[44] (10^6 Mg/yr)	Estimated production @ 50.8% (10^6 Mg/yr)	Control device[44]	No. of furnaces[44]	Fugitive emissions (10^6 kg/yr)	Estimated controlled particulate emissions[A] (10^6 kg/yr)	Estimated copper emissions (10^3 kg/yr)
Northwest Steel Rolling Mills, Inc.							
Kent, WA	0.20	0.10	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Nucor Corp.							
Darlingtron, SC	0.50	0.25	BH	5	0.2	0.21 - 0.23	0.6 - 0.6
Jewell, TX	0.50	0.25	BH	5	0.2	0.21 - 0.23	0.6 - 0.6
Norfolk, NE	0.45	0.23	BH	5	0.2	0.21 - 0.22	0.6 - 0.6
Plymouth, UT	0.36	0.18	BH	2	0.2	0.21 - 0.22	0.6 - 0.6
Oregon Steel Mills							
Gilmore Steel Corp.							
Portland, Ore.	0.18	0.09	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Raritan River Steel							
Perth Amboy, NJ	0.45	0.23	BH	1	0.2	0.21 - 0.22	0.6 - 0.6
Razorback Steel Corp							
Newport, AR	0.20	0.10	BH	2	0.1	0.10 - 0.11	0.3 - 0.3
Roanoke Electric Steel							
Roanoke, VA	0.44	0.22	BH	3	0.2	0.21 - 0.22	0.6 - 0.6
Robin Steel Co.							
Dunkirk, NY	0.16	0.08	BH	3	0.1	0.10 - 0.11	0.3 - 0.3
SMI Steel Corp.							
Birmingham, AL	0.24	0.12	BH	2	0.1	0.11 - 0.11	0.3 - 0.3
Soule Steel Co.							
Carson, CA	0.11	0.06	*	2	0.1	0.10 - 0.11	0.3 - 0.3

(continued)

TABLE 30 (continued)

Company and plant location	Capacity[44] (10^6 Mg/yr)	Estimated production @ 50.8% (10^6 Mg/yr)	Control device[44]	No. of furnaces[44]	Fugitive emissions (10^6 kg/yr)	Estimated controlled particulate emissions[A] (10^6 kg/yr)	Estimated copper emissions (10^3 kg/yr)
Steel of W. VA, Inc. Huntington, WV	0.24	0.24	BH	2	0.2	0.21 - 0.22	0.6 - 0.6
Structural Metals, Inc. Sequin, TX	0.36	0.18	BH	1	0.2	0.21 - 0.22	0.6 - 0.6
TAMCO Ellwanda, CA	0.32	0.16	*	1	0.1	0.11 - 0.12	0.3 - 0.3
Tennessee Forging Steel Corp. Harriman, TN	0.16	0.08	*	3	0.1	0.10 - 0.11	0.3 - 0.3
Thomas Steel Co. Lemont, IL	0.24	0.12	BH	3	0.1	0.11 - 0.11	0.3 - 0.3
Youngstown Steel Corp. Campbell, OH	0.18	0.09	ESP	1	0.1	0.14 - 0.21	0.4 - 0.6
	15.27	7.76		111+			23 - 24

Control Device Codes -
* = Assumed baghouse
BH = Baghouse
Cy = Cyclone
ESP = Electrostatic Precipitator

A Controlled emissions include fugitives @ 0.9 kg/Mg[42] Est. control efficiencies - BH = 99.5%; Cy + BH = 99.7; ESP = 94.0%.

TABLE 31. ELECTRIC ARC FURNACES NOT INCLUDED IN EMISSIONS CALCULATIONS[42]

Company and plant location	No. of furnaces
Allegheny Ludlum - Beckenridge, PA	5
ARMCO - Kansas City, MO	6
Babcock & Wilcox - Beaver Falls, PA	9
Bethlehem - Bethlehem, PA	5
Bethlehem - Steelton, PA	3
Bethlehem - Johnston, PA	2
Bethlehem - Los Angeles, CA	2
Bethlehem - Seattle, WA	2
B & W Steel Co. - Franklin, PA	?
Cabot Corporation - Kokomo, IN	2
Carpenter Technology - Bridgeport, CT	2
Carpenter Technology - Reading, PA	6
CCS Braeburn - Lower Burrell, PA	2
Ceco Corp. - Lemont, IL	3
Ceco Corp. - Milton, PA	3
Colt (Crucible) - Midland, PA	7
Eastern Stainless - Baltimore, MD	2
Electralloy Corp. - Oil City, PA	1
Green River Steel - Owensboro, KY	2
Guter/Special Steel - Lockport, NY	3
Hunt Steel - Youngstown, OH	1
Illinois-Birmingham Bolt - Kankahee, IL	2
Ingersol-Rand - Pampa, TX	1

(continued)

TABLE 31 (continued)

Company and Plant Location	No. of Furnaces
ITT Harper - Morton Grove, IL	2
Jarsco - Roebling, NJ	1
Jessop Steel - Washington, PA	3
LTV (J&L) - Pittsburg, PA	2
Laclede Steel - Alton, IL	2
Lukens Steel - Coatsville, PA	4
Marion Steel - Marion, OH	2
Phoenix Steel - Claymont, DE	2
Ohio River Steel - Calvert City, KY	?
Oklahoma Steel Mill - Oklahoma City, OK	?
Owens Electric Steel Co. of SC - Columbia, SC	3
Quantex Corp. - Jackson, MI	2
- Fort Smith, AR	2
Robin Steel Co. - North Tonawanda, NY	?
LTV (Republic) - Canton, OH	7
- S. Chicago, Ill.	3
Sharon Steel - Sharon, PA	2
Sheffield Steel - Sand Springs, OK	2
Teledyne Vasco - Latrobe, PA	1
Texas Steel Co. - Fort Worth, TX	5
Timken - Canton, OH	8
Union Electric Steel - Burgetstown, PA	1
U.S. Steel - Johnstown, PA	3
- Duquesne, PA	5
Witteman Steel - Fontana, CA	1

COMBUSTION

The combustion of coal and oil is a significant source of copper emissions. Copper emissions were estimated for coal- and oil-fired power plants, industrial boilers, and commercial/institutional boilers by using estimated particulate emissions and applying weight-percentage factors to these particulate emissions. The results are shown in Table 32.

The estimated particulate emissions were obtained from EPA's National Air Data Branch (Personal communication, Ms. Sue Kimbrough, EPA, NADB, August 14, 1984). The weight-percentage factors (0.005-0.04 percent) were obtained from the published literature for analyses of particulate emissions from coal-fired power plant boilers.[3,35,45]

TABLE 32. ESTIMATED COPPER EMISSIONS FROM COMBUSTION SOURCES (1982)

Emission source	Estimated particulate emissions (10^3 Mg/yr)	Estimated copper emissions (10^3 kg/yr) @0.005%	@0.04%	E.F.[A]
Power plants				
Coal - fired				1500
Oil-fired				300
Coal- and oil-fired	576.5[B]	29	230	
Industrial boilers				
Coal-fired	183.5[C]	9.2	73	
Oil-fired	96.8[C]	4.8	39	
Commercial/institutional Boilers				
Coal-fired	26.7[C]	1.3	11	
Oil-fired	15.5[C]	0.8	6.2	
Totals		45	360	1800

A Assuming 90% control and using emission factors of 0.28 kg Cu/10^3 Mg for coal and 0.13 kg Cu/10^3 Bbl for oil.
B Total particulate emissions from EPA, NADB.
C Total particulate emissions from EPA, NADB.

The column entitled "E.F." shows the emission estimate as a product of fuel use and a copper emission factor. The copper emission factor was developed by dividing the total copper emissions in 1976 from both coal-fired and oil-fired utility boilers by the quantity of coal and oil consumed.[3,46] The factors are 2.8 kg Cu/10^3 Mg coal and 1.3 kg Cu/10^3 Bbl oil consumed. Using these factors and coal and oil consumption figures by utility boilers for 1982, the copper emissions for coal-fired and oil-fired utility boilers are 1500 x 10^3 and 300 x 10^3 kg/yr, respectively.

The factor for coal (i.e., 2.8 kg/10^3 Mg) is approximately 1.6 times a factor of 1.8 kg Cu/10^3 Mg coal found reported in the literature.[3] However, the oil factor is almost eighteen times the literature value of 72.6 kg Cu/10^6 Bbl oil.[33]

The copper emissions reported in references 3 and 33 were not defined as either controlled or uncontrolled. With an overall control of about 87.5 percent, the copper emissions would approximate the estimated emissions calculated using the 0.04 percent figure.

Due to the large number of individual coal and oil combustion sources, a detailed examination of each source was not possible. Therefore, a model plant approach was chosen to exam the impact of copper emissions from boilers.

The model-plant characteristics chosen for this exercise were as follows:

Plant size	650 MW
Plant type	coal fired utility
Stack height	175 m
Stack diameter	6.1 m
Exit velocity	20 m/sec
Exit temperature	400° K
Building area	500 m^2
Source type	urban
Estimated copper emissions	300 - 2500 kg/yr

MUNICIPAL INCINERATION

The incineration of municipal refuse results in the emission of both particulate matter and copper. The quantities of these emittants varies due to type of refuse being incinerated, type of incinerator, operating conditions of the incinerator, and type of control equipment.

The estimated copper emissions from municipal incinerators are presented in Table 33. The list of incinerators, their locations, and their capacities were taken from Reference 47. The types of control devices used on the incinerators was taken from Reference 47 and from a list of incinerators currently being compiled by Engineering-Science (EPA Contract No. 68-02-3960, Work Assignment No. 33).

As reported in the literature, uncontrolled particulate matter emissions can vary from 5.0 to 35.0 kg/Mg refuse.[6,48] Test reports indicate uncontrolled emissions of 5.4 to 9.2 kg/Mg (EMB test reports 71-CI-05 and 71-CI-15). For estimates in Table 33, an emission factor of 10.0 kg/Mg refuse was used.

The large number of municipal incinerators and the different configurations lead to a variety of HEM inputs. Thus, a plant-by-plant listing is infeasible. Instead, the default values listed below can be used.

Stack Height	15.2 m
Plant Area	75 m^2
Stack Diameter	0.61 m
Velocity	8.1 m/sec
Temperature	422°K

TABLE 33. ESTIMATED COPPER EMISSIONS - MUNICIPAL INCINERATORS[47]

State and incinerator location	Capacity (Mg/day)[47]	Control device[A]	Assumed control eff. (%)[6]	Estimated particulate emissions[E] (kg/day) Uncontrolled	Controlled	Estimated copper emissions (10^3 kg/yr)[F]
Connecitcut						
Ansonia	181	N	-	1800	-	0.04 - 3.2
Bridgeport (Asylum St.)	181	N	-	1800	-	0.04 - 3.2
Bridgeport (Bostwick Ave.)	181	N	-	1800	-	0.04 - 3.2
East Hartford	318	S	80	3200	640	0.01 - 1.1
New Canaan	113	S	80	1100	230	0.01 - 0.40
Norwalk	327	S	80	3300	650	0.01 - 1.2
Stanford	327	ESP	90	3300	330	0.01 - 0.58
Stanford	136	ESP	90	1400	140	0.003 - 0.24
Florida						
Dade County (N. East)	272	ESP	77.4[B]	1466[B]	332[B]	0.01 - 0.59
Pinellas Co. (U.C.)	1814	N	-	18,000	-	0.38 - 32
Tampa	907	N	-	9100	-	0.19 - 16
Hawaii						
Honolulu (Waipalu)	544	ESP	90	5400	540	0.01 - 0.96
Illinois						
Chicago (Calumet)	1089	N	-	11,000	-	0.23 - 19
Chicago (Northwest)	1452	ESP	90	15,000	1500	0.03 - 2.6
Indiana						
East Chicago	408	S	-	-	1600[C]	2.9[C]
Kentucky						
Louisville	907	N	-	9100	-	0.19 - 16
Louisiana						
Shreveport	181	N	-	1800	-	0.04 - 3.2
Maryland						
Baltimore #4	726	N	-	7300	-	0.15 - 13
Baltimore (Langard)	907	ESP	90	9100	910	0.02 - 1.6
Massachusetts						
Braintree	218	ESP	90	2200	220	0.01 - 0.39
Brockton (E. Bridgewater)	544	BH	97	5400	160	0.003 - 0.29
Fall River	544	S	80	5400	1100	0.02 - 1.9

(continued)

TABLE 33 (continued)

State and incinerator location	Capacity (Mg/day)[47]	Control device[A]	Assumed Control eff. (%)[6]	Particulate emissions[E] (kg/day) Uncontrolled	Particulate emissions[E] (kg/day) Controlled	Estimated copper emissions (10^3 kg/yr)[F]
Framington	544	BH	97	5400	160	0.003 - 0.29
Salem	1089	ESP	90	11,000	1100	0.02 - 1.9
Michigan						
Central Wayne Co.	726	S	80	7300	1500	0.03 - 2.6
Gross Point (Macomb Co.)	544	S	80	5400	1100	0.02 - 1.9
S.E. Oakland Co.	544	S	80	5400	1100	0.02 - 1.9
Missouri						
St. Louis (W.)	363	S	80	3600	730	0.02 - 1.3
St. Louis (S.)	363	S	80	3600	750	0.02 - 1.3
New Hampshire						
Manchester	91	N	-	910	-	0.02 - 1.6
New Jersey						
Red Bank	44	ESP	90	440	44	0.001 - 0.08
New York						
Babylon #1	272	N	-	2700	-	0.06 - 4.8
Buffalo (Westside)	544	G	20	5400	4400	0.09 - 7.7
Glen Cove (U.C.)	204	ESP	90	2000	200	0.004 - 0.36
Hempstead (Messick)	544	ESP	90	5400	540	0.01 - 0.96
Hempstead (Oceanside)	680	ESP	90	6800	680	0.01 - 1.2
Huntington (#1 & #2)	272	N	-	2700	-	0.06 - 4.8
Huntington (#3)	136	N	-	1400	-	0.03 - 2.4
Islip	272	N	-	2700	-	0.06 - 4.8
NYC (Betts)	907	ESP	90	9100	-	0.19 - 16
Lackawanna	136	N	-	1400	-	0.03 - 2.4
NYC (Greenpoint)	907	N	-	9100	-	0.19 - 16
NYC (Hamilton)	907	N	-	9100	-	0.19 - 16
NYC (S.W. Brooklyn)	907	ESP	44.8	8300[D]	4600[D]	0.10 - 8.2
Oyster Bay #1	454	N	-	4500	-	0.09 - 8.0
Oyster Bay #2	454	N	-	4500	-	0.09 - 8.0
Tonawanda (City)	73	N	-	730	-	0.02 - 1.3

(continued)

TABLE 33. Continued

State and incinerator location	Capacity (Mg/day)[47]	Control device[A]	Assumed Control eff. (%)[6]	Particulate emissions[E] (kg/day) Uncontrolled	Controlled	Estimated copper emissions (10^3 kg/yr)[F]
Tonawanda (Town)	227	N	-	2300	-	0.05 - 4.0
Ohio						
Dayton (S. Montgomery Co.)	544	S	80	5400	1100	0.02 - 1.9
Dayton (N. Montgomery Co.)	544	S	80	5400	1100	0.02 - 1.9
Euclid	181	N	-	1800	-	0.04 - 3.2
Lakewood	272	ESP	90	2200	220	0.01 - 0.48
Pennsylvania						
Bradford	181	N	-	1800	-	0.04 - 3.2
Harrisburg	653	ESP	90	6500	650	0.01 - 1.2
Philadelphia (E. Central)	544	S, ESP	98	5400	110	0.002 - 0.19
Philadelphia (N.W.)	544	ESP	90	5400	540	0.01 - 0.96
Rhode Island						
Pantucket	363	N	-	3600	-	0.08 - 6.4
Tennessee						
Nashville	653	ESP	90	6500	650	0.01 - 1.2
Utah						
Ogden	136	ESP	90	1400	140	0.003 - 0.24
Virginia						
Hampton (U.C.)	181	ESP	90	1800	180	0.004 - 0.32
Newport News	363	S	80	3600	730	0.02 - 1.3
Norfolk (Navy)	327	ESP	90	3300	330	0.01 - 0.58
Portsmouth	318	S	80	3200	640	0.01 - 1.1
Portsmouth (Navy)	136	ESP	90	1400	140	0.003 - 0.24
Wisconsin						
Shaboygan	218	S	80	2200	440	0.01 - 0.77
Waukesha	318	ESP	90	3200	320	0.01 - 0.56
WASHINGTON, D.C.						
S. W. Red. Center #1	1361	ESP	90	14,000	1400	0.03 - 2.4
					Totals	3.3 - 270

A Control device codes - S = scrubber ESP = electrostatic precipitator G = Gravity
N = none; unknown BH = baghouse

B EMB test No. 71-CI-05

C Based on 4.0 kg/Mg refuse (Ref. 35)

D Based on EMB Test No. 71-CI-15; E.F. of 5.08 kg/Mg controlled, 9.20 kg/Mg uncontrolled

E Assume 10 kg/Mg refuse

F Based on 5 days/week and 52 weeks/yr operation, and Cu of 0.008 - 0.68% 52,53

SECONDARY COPPER

The Bureau of Mines stated that in 1981, forty-three secondary copper smelters produced 0.49 x 10^6 Mg of copper from scrap.[49] Predicasts® estimated that 1.38 x 10^6 Mg of secondary copper was produced, including secondary copper produced at primary smelters.[50] A study conducted by EPA in 1980 listed seven secondary smelters that "... smelt and refine copper scrap to produce pure copper or copper alloy (other than brass and bronze)."[51] In the EPA report, data were presented on six of these seven smelters.

Estimated copper emissions from the six plants are shown in Table 34. These six plants account for approximately 77 percent of the secondary copper produced. For Table 34, the estimated particulate emissions were taken from Reference 51, and copper compositions were taken from Reference 51 and from the factors used on primary copper smelters. Fugitive emissions were estimated for slag cleaning furnaces, cupolas, and reverberatory furnaces.[6]

Typical HEM inputs for secondary copper smelting and refining plants are shown in Table 35.[53]

TABLE 35. TYPICAL HEM INPUT VALUES - SECONDARY COPPER SMELTERS AND REFINERS

Operation	Stack height (m)	Flow rate (m^3/sec)	Temperature (°K)
Cupola	23	28.3	366
Rotary converter	23	18.9	400
Reverberatory anode furnaces	17	22.7*	351
Reverberatory fire refining furnace	17	9.4	351
Shaft furnace	17	12.2	520

* Flow rate for two identical furnaces.

MISCELLANEOUS SOURCES OF COPPER EMISSIONS

Sections 4.1 to 4.6 describe the major sources of copper emissions. Many other sources have been demonstrated to be emitters of copper. These emitters are either small or complete information is not available. Among these sources are copper compound production, foundries, lead smelting, primary and secondary zinc smelting, ferroalloys, brass and bronze, and carbon black.

Natural or nonindustrial sources of copper emissions also exist. Among these are the open dust sources, paved and unpaved roads, agricultural tilling, construction, mining refuse piles, and possibly coal refuse piles. Wind action on soil and rock is an important activity common to all these sources.

TABLE 34. ESTIMATED COPPER EMISSIONS - SECONDARY COPPER SMELTERS[51]

Company and plant location	Estimated production[51] (10^3 Mg/yr)	Estimated particulate emissions (controlled) (10^3 kg/yr)		Estimated coppper emissions[B] (10^3 kg/yr)	Process equipment (furnaces)
		Process	Fugitive		
Cerro Copper Prod. East St. Louis, IL	48	63	130	19	Billet, reverb, shaft
CHEMETCO Alton, IL	27	210	C	8.4	Holding, Kaldo
Franklin Smelting & Refining Philadelphia, PA	18	49	33	0.8	Convector, cupola
Nassau Recycling Gaston, SC	76	380	220	58	Reverb
Southwire Carrollton, GA	33	100	150	14	Convertor, cupola, holding, reverb, shaft
US Metals Refining Carteret, NJ	170	290	790	58	
TOTALS	372			160	

A Fugitive emission factors based on scrap processed. To calculate scrap, the equation Cu produced = 3.037 x charge was used. However, charge includes other things besides scrap. Therefore, fugitives based on production are probably lower than actual.

B Estimated copper content of emissions - Billet 9.9%, Convertor 4%, Cupola 0.5%, Holding 0.5%, Kaldo 4%, Reverberatory 9.9%, Shaft 9.9%, Slag cleaning 0.8%

C Fugitive emission factors are not available for holding and Kaldo furnaces.

Soils, as weathered products of rock, would contain copper. The behavior of copper during weathering supports this statement. Copper sulfides are readily oxidized to sulfates, and copper is released as Cu^{++}. This ion is very mobile in solution and can reform into sulfides in a reducing environment or into carbonates when limestones are encountered. In acidic environments, copper is likely to be concentrated into commercial deposits.[54]

Copper Compounds

Many copper compounds are produced. Most copper compounds considered to be of importance in industrial applications are produced from copper metal. Copper compounds are used as fungicides, insecticides, herbicides, antifoulants (in paints), catalysts, corrosion inhibitors, flameproofers, fuel oil additives, wood preservatives, and as additives in such products as glass, ceramics, cement, medicines, food, drugs, metal alloys, nylon, paper, pigments and dyes, printing and photocopying, and pyrotechnics.[55] Although many copper compounds are produced, the most commercially important are acetates, acetylides, arsenates, bromides, carbonates, chlorides, chromates, ferrates, hydroxides, nitrates, nitrates, oxides, and sulfates.[55]

A search of the literature for emissions data for the production of copper compounds revealed very little. One reference source estimated that 34.5×10^3 kg/year of copper sulfate were emitted from the production of copper sulfate pentahydrate in 1977.[3] Production of copper sulfate during 1977 was 27,306 Mg.[49] Thus, 1.26 kg of copper sulfate is emitted per Mg of copper sulfate produced. Copper sulfate production in 1981, was 35,636 Mg.[49] Useing the 1.26 kg/Mg emission factor, copper sulfate emissions of 45×10^3 kg/year would be expected.

Iron Foundries

In 1976, 1,367 iron foundries were operating in the United States (see Table 36).[56] At that time, the industry trend was a reduction in the number of foundries and an increase in the average size of foundries. The production of iron castings has been cyclical but decreasing since 1965.[56] In 1982, shipments of gray and ductile iron castings were 7.4×10^6 Mg.[50]

Uncontrolled, process particulate-emission factors as given in AP-42 are 8.5 kg/Mg of gray iron produced from cupolas. Emissions from electric arc, electric induction, and reverberatory furnaces are lower.

Fugitive emission factors (emitted to atmosphere) are as follows:

	kg/Mg
Scrap and charge handling; heating	0.1
Pouring	1.0
Cooling	0.5
Shakeout	0.5
Cleaning, finishing	0.05
Sand handling, preparation, mulling	1.5

The copper composition of the particulate emissions is relatively low; 0.006 percent (wt.) for a green-sand shakeout and 0.02 percent (wt.) for pouring and innoculation emissions.[56,57] Data on copper content of furnace emissions are not available.

As a conservative estimate of total copper emissions from iron foundries, the following assumptions are used:

1. All foundries use a cupola as the melting furnace,
2. Emissions control is 80 percent,
3. No controls exist for fugitive emissions, and
4. The copper content of the emissions is 0.02 percent (wt.).

Based on 1982 shipments of gray and ductile iron castings, 7.9×10^3 kg of copper emissions are expected.

TABLE 36. DISTRIBUTION OF IRON FOUNDRIES IN 1976[56]

State	Iron Foundries	State	Iron Foundries
Alabama	64	Missouri	26
Alaska	1	Montana	3
Arizona	3	Nebraska	8
Arkansas	9	Nevada	2
California	8	New Hampshire	8
Colorado	12	New Jersey	29
Connecticut	20	New Mexico	1
Delaware	1	New York	66
D. C.	1	North Carolina	27
Florida	12	North Dakota	2
Georgia	25	Ohio	152
Hawaii	2	Oklahoma	22
Idaho	4	Oregon	12
Illinois	81	Pennsylvania	157
Indiana	75	Rhode Island	8
Iowa	35	South Carolina	12
Kansas	23	South Dakota	1
Kentucky	13	Tennessee	40
Louisiana	8	Texas	66
Maine	8	Utah	12
Maryland	10	Vermont	4
Massachusetts	43	Virginia	29
Michigan	111	Washington	18
Minnesota	35	West Virginia	13
Mississippi	7	Wisconsin	88
		Total	1,367

Lead Smelters

In 1981, six primary lead smelters were operating in the United States and producing 495.3 x 10^3 Mg of primary lead.[58] During 1981, the Bunker Hill Company of Kellogg, Idaho closed after eleven months of production.[58]

Estimated copper emissions from primary lead smelters are shown in Table 37. Fugitive emissions are the largest source of copper emissions. Typical HEM inputs are shown in Table 38.

Zinc Smelters

In 1981, seven plants produced 343.7 x 10^3 Mg of primary slab zinc.[59] Of the seven, four used the electrolyte process, and three used the pyrometallurgical. Emissions information for zinc smelters is sketchy. For the purposes of this study, all pyrometallurgical plants were assumed to have roasting, sintering , and vertical retorts. Electrolytic plants were assumed to have roasting and electrolytic processes.

Estimated copper emissions from the fine primary slab-zinc processing plants currently operating are shown in Table 39. Uncertainty in the types of process and control equipment, especially on the roasters, at individual smelters make these numbers appear to be high. However, fugitive process emissions are not included in these estimates, due to a lack of emissions data. Typical HEM inputs are shown in Table 40.

TABLE 40. HEM DATA - PRIMARY ZINC SMELTERS

Company and locations	Stack height (m)	Area (m^2)	Diameter (m)	Velocity (m/sec)	Temperature (°K)
AMAX, Inc. Sauget, IL	45.7	100	1.5	9.7	373
ASARCO, Inc. Corpus Christi, TX	91.5	100	2.0	2.7	389
Jersey Minier Zinc Clarksville, TN	61.0	100	1.8	6.3	334
National Zinc Co. Bartlesville, OK	30.5	100	1.3	5.7	325
St. Joe Minerals Corp.[A] Monaco, PA	40.2	100	2.3	5.2	328

[A] Four unidentified point sources reported in HEM printout. Values reported here are averages.

TABLE 37. ESTIMATED COPPER EMISSIONS - PRIMARY LEAD SMELTERS

Company and plant location	Estimated capacity[7] (10^3 Mg/yr)	Estimated 1981 production[58] (10^3 Mg/yr)	Estimated controlled particulate emissions (10^3 kg/yr)[A]		Estimated fugitive emissions[H] (10^3 kg/yr)	Estimated copper emissions (10^3 kg/yr)[I]	
			Smelter	Refinery		Smelter	Refinery
AMAX							
Boss, MO	127	91.4	32[B]	1.5[C]	370	1.2-14	0.001
ASARCO							
East Helena, MT	109	50.1	17[D]	-	200	0.7-8	
El Paso, TX	109	50.1	17[E]	-	200	0.7-8	
Glover, MO	100	69.6	24[F]	1.1[G]	280	0.9-11	0.001
St. Joe Minerals Corp.							
Herculaneum, MO	204	152.4	53[B]	2.5[C]	620	2.0-24	0.002
						5.5-65	Neg.

A Emission factors - Smelter - Sinter = 0.051 kg/Mg; blast furnace = 0.294 kg/Mg (Ref. EMB-73-PLD-1)
Refinery - 0.016 kg/Mg[6].
B Acid plant on strong stream, baghouse on weak stream of sinter; baghouse or blast furnace.
C Baghouse.
D Water spray and ESP on sinter; baghouse on blast furnace.
E Scrubber and baghouse on sinter; water spray and baghouse on blast furnace.
F Water spray and baghouse on sinter and blast furnace.
G Water spray and baghouse.
H Emission factor of 4.09 kg/Mg[6].
I Copper content of emissions - sinter 0.3 - 4.5 wt. %[7]; blast furnace 0.29 wt. % [60]; refining furnaces 0.005-0.080 wt. %.[7]

TABLE 38. HEM DATA - PRIMARY LEAD SMELTERS

Company and plant location	Stack Height (m)	Area (m^2)	Diameter (m)	Velocity (m/sec)	Temperature (°K)
AMAX					
Boss, MO	61	100	4.6	10.0	355
ASARCO					
East Helena, MT[A]	127	100	3.0	15.9	352
El Paso, TX[B]	139	100	4.6	10.0	340
Glover, MO	24	100	1.5	18.3	294
St. Joe Minerals Corp.					
Herculaneum, MO	107	100	6.1	13.5	353

A Three unidentified point sources reported in HEM printout. Values reported here are averages.

B Two unidentified point sources reported in HEM printout. Values reported here are averages.

TABLE 39. ESTIMATED COPPER EMISSIONS - PRIMARY SLAB ZINC PRODUCTION

Company and plant location[A]	Process Type[B]	Capacity[7,59] (Mg/yr)	Estimated 1981 production (Mg/yr)	Estimated controlled emissions (10^3 kg/yr) Particulate[E]	Copper[F]
AMAX, Inc.					
Sauget, IL	E	76,000	67,680	1,400	6.1 - 85
ASARCO, Inc.					
Corpus Christi, TX	E	104,000	46,900	980	4.2 - 59
Jersey Minier Zinc					
Clarksville, TN	E	82,000	55,920[D]	1,200	5.0 - 71
National Zinc Co.					
Bartlesville, OK	E	51,000	51,000	1,100	4.6 - 64
St. Joe Minerals Corp.					
Monaco, PA	P	68,000[C]	46,370	1,500	4.4 - 59
					24-340

A Taken from Reference 7 and modified by Reference 59.
B E = electrolytic; P = pyrometallurgical.
C Slab capacity, total capacity of 103,000 Mg/yr.
D Estimated by capacity utilization ratio of 68.2%.
E Emissions estimated by:
Electrolytic plants - Roaster E.F. - 120 kg/Mg[6] Control = 85% (est.)[7]
Electrolytic E.F. = 3.0 kg/Mg[6,7] Control = 0%[7]
Pyrometallurgical plants - Roaster E.F. - 120 kg/Mg[6] Control = 85%[7]
Sintering E.F. = 8.25 kg/Mg (controlled)[35]
Vertical retort E.F. = 7.15 kg/Mg[35]
F Emissions estimated by copper percentages (wt.) of: Roasters - 0.50 - 7.0% [7,36]
Sinters - 0.042%[35]
Retorts - 0.014%[30]
Electrolytic - 0.0085%[7]

Other zinc processing plants, such as slag fuming plants, zinc oxide plants, galvanized metal plants, and secondary slab zinc plants, have the potential to emit copper compounds. Lists of these plants, along with available capacity data, are presented in Tables 41 through 43.

TABLE 41. ZINC SLAG FUMING PLANTS[59]

Plant and location	Estimated capacity (Mg/yr)
ASARCO, Inc. El Paso, TX East Helena, MT	27,400
Bunker Hill Co. Kellogg, ID	-

TABLE 42. PARTIAL LIST OF ZINC OXIDE PLANTS[59]

Plant and location	Estimated capacity (Mg/yr)	Other products
ASARCO, Inc. Columbus, OH Hillsboro, IL	51,000*	
Huron Valley Steel Corp. Trenton, MI	22,000	
New Jersey Zinc Palmerton, PA	87,000	Zinc dusts and powders
Pacific Smelting Co. Memphis, TN Torrance, CA	36,000	Galvanized zinc metals

* 1981 production.

TABLE 43. SECONDARY SLAB ZINC PRODUCERS[59]

Plant and location	Estimated capacity (Mg/yr)
Arco Alloys Corp., Detroit, MI Belmont Smelting & Refining Works, Brooklyn, NY W. J. Bullock, Inc., Fairfield, AL T. L. Diamond & Co., Inc., Spelter, WV Huron Valley Steel Corp., Belleville, MI Illinois Smelting & Refining Co., Chicago, IL Interamerican Zinc Co., Adrian, MI New England Smelting Works, Inc., West Springfield, MA The New Jersey Zinc Co., Dupue, IL Prolerized Schiabo Neu Co., Jersey City, NJ Los Angeles, CA Pacific Smelting Co., Torrance, CA S-G Metals Industries, Inc., Kansas City, KS	90,000

Ferroalloys

Uncontrolled particulate matter emissions from electric smelting furnaces used to produce ferralloys can be substantial. For open furnaces, emissions of 97.5 to 312.5 kg/Mg product have been reported for silicomanganese and silicon metal, respectively.[6] Emissions for the other types of ferroalloys are between these two values. Controlled emissions from a variety of furnace types producing a variety of ferroalloys range from 0.062 to 4.75 kg/Mg.[61] Copper concentrations of 0.03 to 0.05 percent (wt.) have been reported.[62]

Total estimated copper emissions from ferroalloy production furnaces are $1.9 - 3.2 \times 10^3$ kg/yr. These emissions were calculated by using the total estimated particulate emissions from ferroalloy production (1981) and the 0.03 to 0.05 wt. percent copper concentrations.

Brass and Bronze

In 1982, thirty-seven secondary brass and bronze facilities produced over 154,000 Mg of brass and bronze ingots.[63] According to the NEDS inventory, 3.6×10^3 Mg of particulate matter emissions were generated (Personal communication, Ms. Sue Kimbrough, EPA, NADB, August 29, 1984). This emissions figure resulted from the total particulate emissions from secondary copper furances using brass/bronge charges.

Furnace dust concentrations of copper are reported to be 0.05 to 1.0 percent (wt.).[63] Using these numbers, copper emissions of 1.8 to 36×10^3 kg/yr are expected.

Carbon Black

Carbon black vent gases contain copper, as well as other substances. One study showed a copper content of 0.45 percent (wt.) copper in the main process vent particles.[64] Total particulate emissions of 2778 Mg/yr from carbon black plants have been estimated (Personal communication, Ms. Sue Kimbrough, EPA, NADB, August 29, 1984). Estimated copper emissions are 13×10^3 kg/yr.

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APPENDIX

Example Calculation of Copper Emissions

From Primary Copper Smelters

Notes to Appendix

Production - Production figures were available for 1979 and 1980. In 1980, the industry was hit by a strike, and production was decreased. Therefore, 1979 production data were used.

NSP Review - Refers to the review document for NSPS for primary copper smelters (Reference 19).

Reference numbers refer to References for Section 5.

Common Abbreviations

E.F. = Emission Factors
E_u = Emissions, uncontrolled
E_c = Emissions, controlled
Est. = Estimated
Mg = 10^6 grams
kg = 10^3 grams

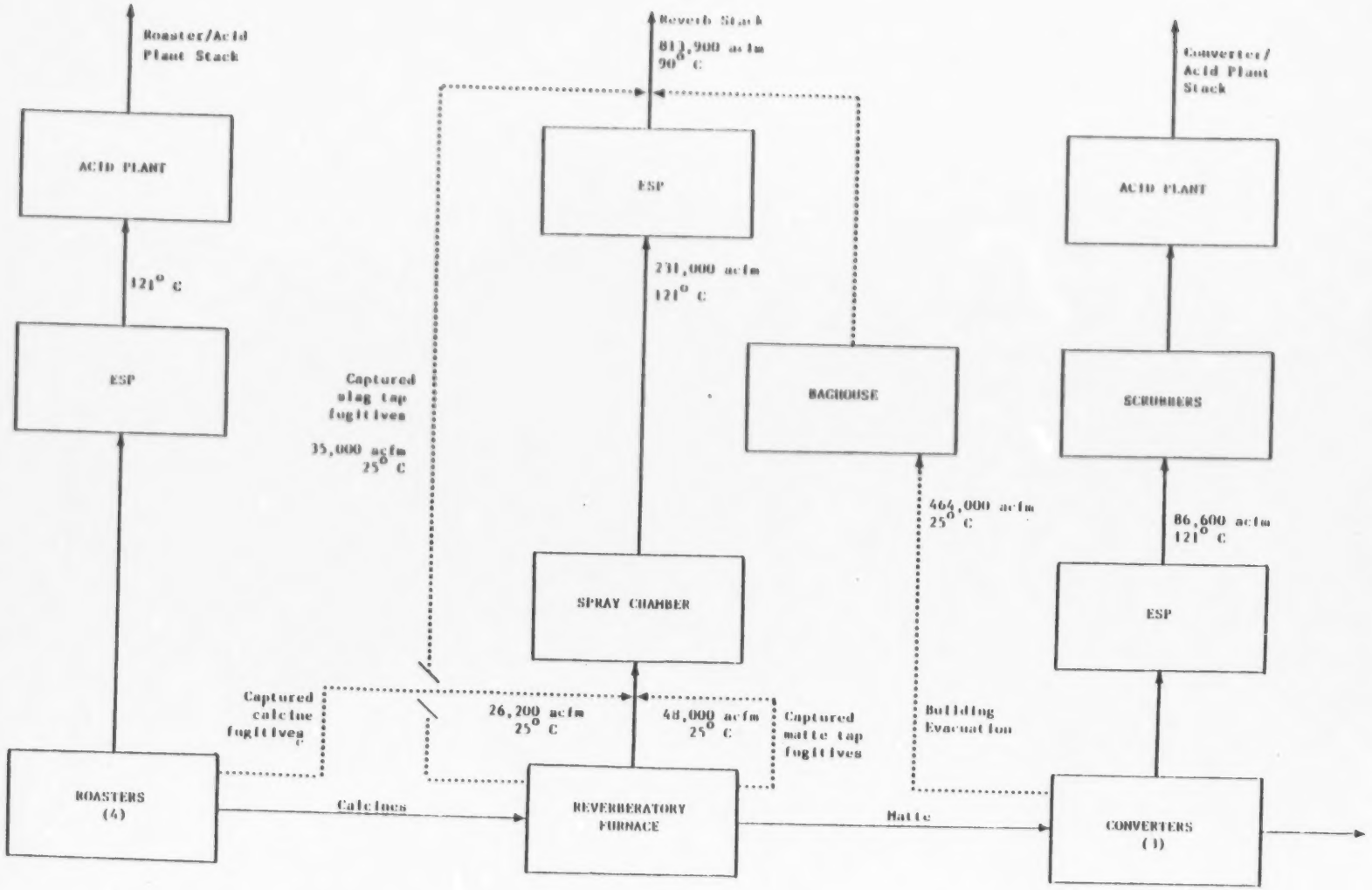

Figure A-1. Process Flow Diagram - ASARCO, El Paso

ASARCO, INC.

El Paso, Texas

Capacity - 104×10^3 Mg/yr [18]

91×10^3 Mg/yr

1979 Production - 85.0×10^3 Mg/yr [19]

A. Emissions - Total Particulate

I. Multihearth Roasters (4)

A. Process Emissions - ESP & Acid Plant Controlled

NSPS Review [19]

E.F. = 90 kg/Mg Cu

$E_u = (90 kg/Mg)(85{,}000 Mg/yr) = 7.7 \times 10^6$ kg/yr

Control Efficiency

ESP = 96.6% [40]

Acid Plant = 88% [40]

$E_c = (7.7 \times 10^6 kg/yr)(0.034)(0.12) = 31.4 \times 10^3$ kg/yr

Test [21]

$E_u = (480.8 kg/hr)(8424 hr/yr) = 4.1 \times 10^6$ kg/yr

$E_c = (4.1 \times 10^6 kg/yr)(0.034)(0.12) = 16.7 \times 10^3$ kg/yr

B. Fugitive Emissions - Spray Chambers & ESP Controlled (Partial)

NSPS Review [19]

E.F. = 5.2 kg/Mg Cu

$E_u = (5.2 kg/Mg)(85{,}000 Mg/yr) = 442.0 \times 10^3$ kg/yr

Estimated Hood Capture Efficiency = 50%

Estimated Control Efficiency

ESP = 96.9% [40]

Spray Chamber + ESP = 99.0%

$E_c = (442.0 \times 10^3 \text{ kg/yr})(0.5)(0.01) + (442.0)(0.5)$

$E_c = 223.2 \times 10^3 \text{ kg/yr}$

Test [21]

E.F. = 0.949 kg/hr

$E_u = (0.949 \text{ kg/hr})(8424 \text{ hr/yr}) = 7.9 \times 10^3 \text{ kg/yr}$

$E_c = (7.9 \times 10^3 \text{ kr/yr})(0.50)(0.01) + (7.9)(0.50) = 4.0 \times 10^3 \text{ kg/yr}$

II. Reverberatory Furnaces

A. Process Emissions - Spray Chambers & ESP Controlled

NSPS Review [19]

E.F. = 40 kg/Mg Cu

$E_u = (40 \text{ kg/Mg})(84{,}000 \text{ Mg/yr}) = 3.4 \times 10^6 \text{ kg/yr}$

Control Efficiency (Estimated) = 99.0% [40]

$E_c = (3.4 \times 10^6 \text{ kg/yr})(0.01) = 34.0 \times 10^3 \text{ kg/yr}$

Test [21]

$E_u = (418.7 \text{ kg/hr})(8424 \text{ hr/yr}) = 3.5 \times 10^6 \text{ kg/yr}$

$E_c = (3.5 \times 10^6 \text{ kg/yr})(0.01) = 35.0 \times 10^3 \text{ kg/yr}$

B. Fugitive Emissions - Uncontrolled Slag; Spray Chamber & ESP Controlled Matte (partial)

NSPS Review [19]

Slag Tapping

E.F. = 0.31 kg/Mg Cu

$E_u = (0.31 \text{ kg/Mg})(85{,}000 \text{ Mg/yr}) = 26.4 \times 10^3 \text{ kg/yr}$

Matte Tapping

E.F. = 0.34 kg/Mg Cu

Est. Captive Efficiency - 40% [25]

Est. Control Efficiency - 90% [40]

E_u = (0.34 kg/Mg)(85,000 Mg/yr) = 28.9 x 10^3 kg/yr

E_c = (228.9 x 10^3)(0.40)(0.01) + (28.9 x 10^3)(0.60)

E_c = 17.5 x 10^3 kg/yr

Total E_c = 43.9 x 10^3 kg/yr

Test [20]

Matte Tapping only

E_u = (1.2 kg/hr)(8424 hr/yr) = 10.1 x 10^3 kg/yr

E_c = (10.1 x 10^3)(0.40)(0.01) + (10.1 x 10^3)(0.60) =

6.1 x 10^3 kg/yr

Total E_c = 32.5 x 10^3 kg/yr

III. Converters

A. Process Emissions - ESP, Scrubber + Acid Plant Controlled

NSPS Review [19]

E.F. = 120 kg/Mg Cu

E_u = (120 kg/Mg)(85,000 Mg/yr) = 10.2 x 10^6 kg/yr

Estimated Control Efficiency

ESP = 92.9% [40]

ESP + Acid Plant = 99.1% [40]

Scrubber = 90% (Estimate)

Total = 99.9%

E_c = (10.2 x 10^6 kg/yr)(0.001) = 10.2 x 10^3 kg/yr

B. Fugitive Emissions - Baghouse Controlled (Partial)

NSPS Review [19]

E.F. = 10 kg/Mg Cu

E_u = (10 kg/Mg)(85,000 Mg/yr) = 850.0 x 10^3 kg/yr

Est. Collection Efficiency of Hood - 75% [21]

Average Efficiency of Baghouse - 91.2% [21]

E_c = (850.0 x 10^3)(0.75)(0.088) + (850 x 10^3)(0.25)

E_c = 268.6 x 10^3 kg/yr

Test [21]

Emissions

Uncontrolled = 50.7 kg/hr

Controlled = 4.43 kg/hr

E_c = (4.43 kg/hr)(8424 hr/yr) + (16.9 kg/hr)(8424 kg/yr)*

$E_c = 179.6 \times 10^3$ kg/yr

*With 75% collection, 16.9 kg/hr are not captured by the hood

B. Emissions - Copper

I. Roasters

Copper = 1.0 wt. %

Process

Particulate Emission Range = $16.7 \times 10^3 - 31.4 \times 10^3$ kg/yr

Cu Emission Range = $0.2 \times 10^3 - 0.3 \times 10^3$ kg/yr

Fugitive

Particulate Emission Range = $4.0 \times 10^3 - 223.2 \times 10^3$ kg/yr

Cu Emission Range = $0.04 \times 10^3 - 2.2 \times 10^3$ kg/yr

II. Reverberatory Furnaces

Copper = 0.068 - 17.2 wt. %

Process

Particulate Emissions Range - $34.0 \times 10^3 - 35.0 \times 10^3$ kg/yr

Cu Emissions Range = $0.02 \times 10^3 - 6.0 \times 10^3$ kg/yr

Fugitive

Particulate Emissions Range = $32.5 \times 10^3 - 43.9 \times 10^3$ kg/yr

Cu Emissions Range = $0.02 \times 10^3 - 7.6 \times 10^3$ kg/yr

III. Converters

Copper = 0.15 - 19.0 wt. %

Process

Particulate Emissions 10.2×10^3 kg/yr

Cu Emissions Range = 0.02×10^3 - 1.9×10^3 kg/yr

Fugitive

Particulate Emission Range = 179.6×10^3 - 268.6×10^3 kg/yr

Cu Emissions Range = 0.3×10^3 - 51.0×10^3 kg/yr

C. Estimated Total Copper Emissions

	Emissions (10^3 kg/yr)		
Source	Process	Fugitive	Total
Roasters	0.2 - 0.3	0.04 - 2.2	0.2 - 2.5
Reverberatory Furnaces	0.02 - 6.0	0.02 - 7.6	Neg. - 13.6
Converters	0.02 - 1.9	0.3 - 51.0	0.3 - 52.9
Totals	0.2 - 8.2	0.4 - 60.8	0.6 - 69.0